STEREO
Subsystem Telemetry Assessment

September 19, 2018

Dan Wilson

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APPLIED PHYSICS LABORATORY

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Overview

- **The subsystem assessment review is a formal opportunity for all of the subsystems to report their status as it pertains to:**
  - Subsystem performance
  - Overview of major subsystem activities
  - Anomalous behaviors
  - Changes in nominal operating conditions
  - Trends that could impact future operations

- **Each subsystem lead engineer will be given ~15 minutes to present to the project team their findings**
  - G&C has 30 minutes
  - Subsystem engineers are encouraged to participate for entire assessment review

- **Goals of subsystem assessment:**
  - Formally assess the spacecraft health and performance in the recent past
  - Identify any changes that could be made to improve performance
  - If necessary, present preventative actions that could be taken to mitigate against future failures or degraded performance

Review Period

- May 1st, 2016 through Jun 30th, 2018
  - AHEAD observatory only
  - BEHIND first recovery attempt Aug 21st through Sep 23rd, 2016
    - No new telemetry available since the last Telemetry Assessment was held in February 2017
- The previous review for AHEAD was held on June 24th, 2016. Materials from the review can be found at:

\\davis\project\Stereo\System Engineering\Telemetry Assessments - Post Launch\2016 Spring Assessment

- To assist with analysis, detailed mission event history is in the link below.

\\davis\project\Stereo\System Engineering\Telemetry Assessments - Post Launch\2018 Assessment

Subsystem Telemetry

- **Each lead engineer should report on the regularly monitored telemetry associated with their subsystem**
  - **The Excel spreadsheet below contains the list of points that MOps plots for operational assessment and is provided as a reference (double click to open)**
    - **Yesterdaily (every sample)**
    - **Weekly and Quarterly (hourly averaged)**
    - **Monthly (daily averaged)**
    - **Annual (weekly averaged)**
  - **These plots are located in the STEREO MOps webpage below (select: Assessment, and Assessment again)**

http://so.jhuapl.edu/

Plot_Definitions_090518.xls

Subsystem Presentation Outline

- **Subsystem performance and health since last review**
  - Review regular trending telemetry points that are plotted by MOps and report any abnormal findings
  - Report findings on any additional subsystem telemetry
  - Identify any changes that could be made to improve system performance
- **Identify any possible trends in telemetry data that should be closely monitored as it pertains to future failure or performance degradation**
  - Provide any mitigating action that could be taken
- **List major milestones and/or activities related to the subsystem**
  - Report any major changes to the nominal operations of the subsystem
- **Significant anomalies experienced by the subsystem since last review**
  - Provide a brief overview and any mitigations taken as a result of the anomaly
- **Briefly address applicable action items, if any, from previous review**

Agenda

Time Period	Subsystem	Responsible Lead Engineer
09:00	Introduction	Dan Wilson
9:10	Guidance and Control	Jack Hunt
9:40	Autonomy	Kevin Balon
9:55	Flight Software	Kevin Balon
10:10	Thermal	Jeff Maynard
10:25	Power	Mike Butler
10:40	RF	Dipak Srinivasan
10:55	IEM	Dave Bort
11:10	Propulsion	Stewart Bushman

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19 September 2016

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Summary

- **Significant G&C system configuration changes since last assessment review (2016.06.15)**

  None

  - **Still operating with:**
    - **No IMU for all routine ops**
    - **ST thermo-electric cooler set point lowered to -10° C**
  - **No Behind data available for assessment**
- **Generally, pointing performance has been good**
  - **Parameters continue to be tuned, as necessary.**
- **Momentum dumps continue to go well**
  - **First gyroless momentum dump performed Dec, 2015**
  - **Gyroless momentum dumps are now routine**
- **Several anomalies (discussed later)**

Significant G&C-Related Events

- 24 May 2016 (doy 145) – Wheel speed avoidance band about zero increased
  - New value: 30.79 rad/s
- 6 Feb 2017 (doy 037) – Changed Autonomous Dump thruster set to B-thrusters
- 20 Feb 2017 (doy 051) – Changed SlewMaxRate parameter
  - As part of autonomy reconfiguration for No-Gyro-Ops
- 29 Aug 2017 (doy 241) – Star Tracker Reset (CPU Error); 6th since launch
  - Occurred @ 11:32:38z; Recovered @ 11:32:57z
- 29 Apr 2018 (doy 119) – Star Tracker Reset (CPU Error); 7th since launch
  - Occurred @ 15:20:46z; Recovered @ 15:24:01z
- Multiple intermittent fine pointing anomalies for different reasons
  - Wheel Speed Avoidance convergence failures
  - Low wheel speeds (One or more wheels running for a prolonged period at or near the zero-speed avoidance threshold)

Assessment Approach

- **Daily housekeeping data is evaluated**
  - **If something looks "interesting" it is pursued**
  - **Generally problems with hardware will reveal themselves in degraded attitude performance and lead to investigation**

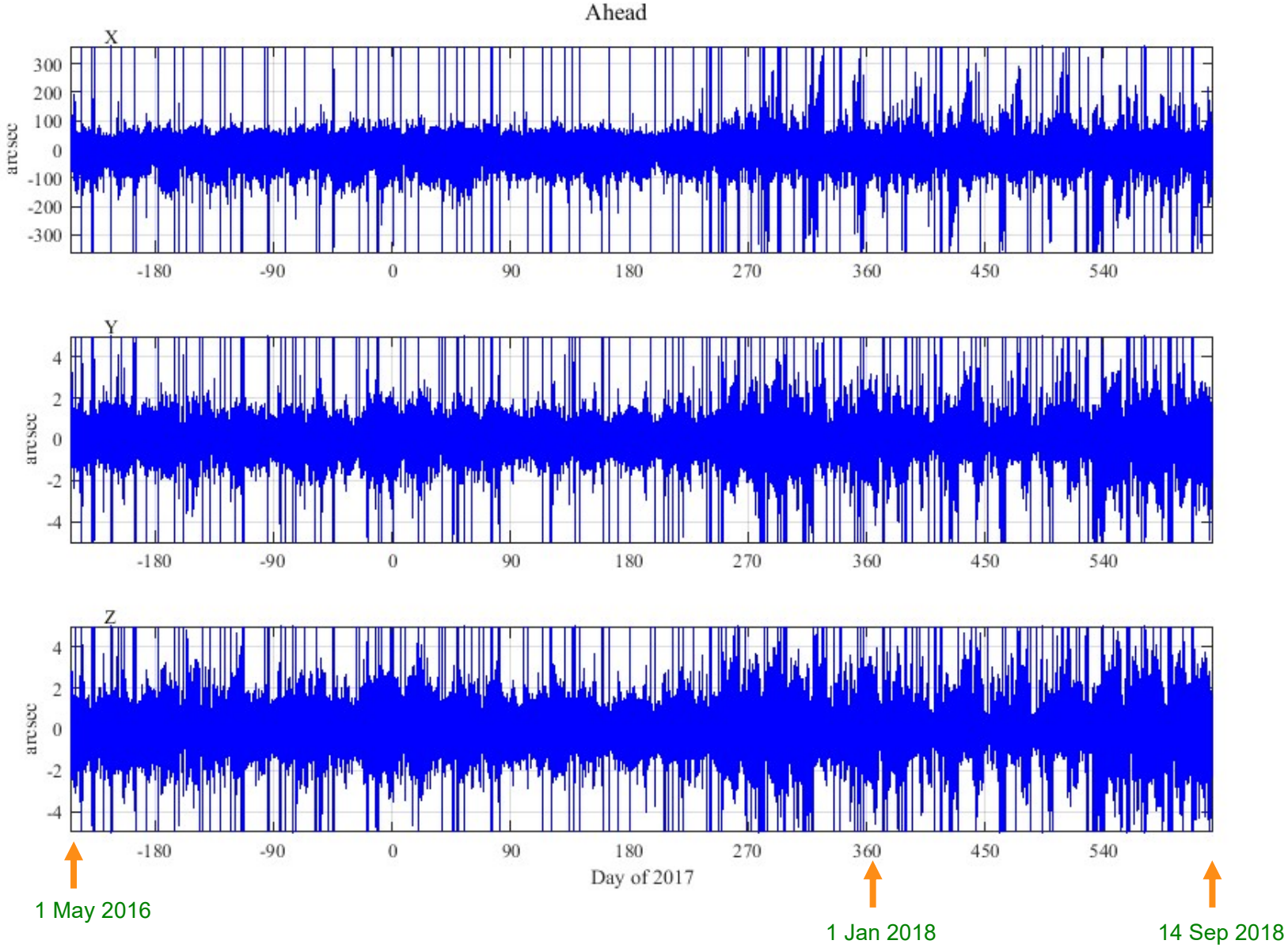
- **Plots follow……..**

Period of Data Evaluation:

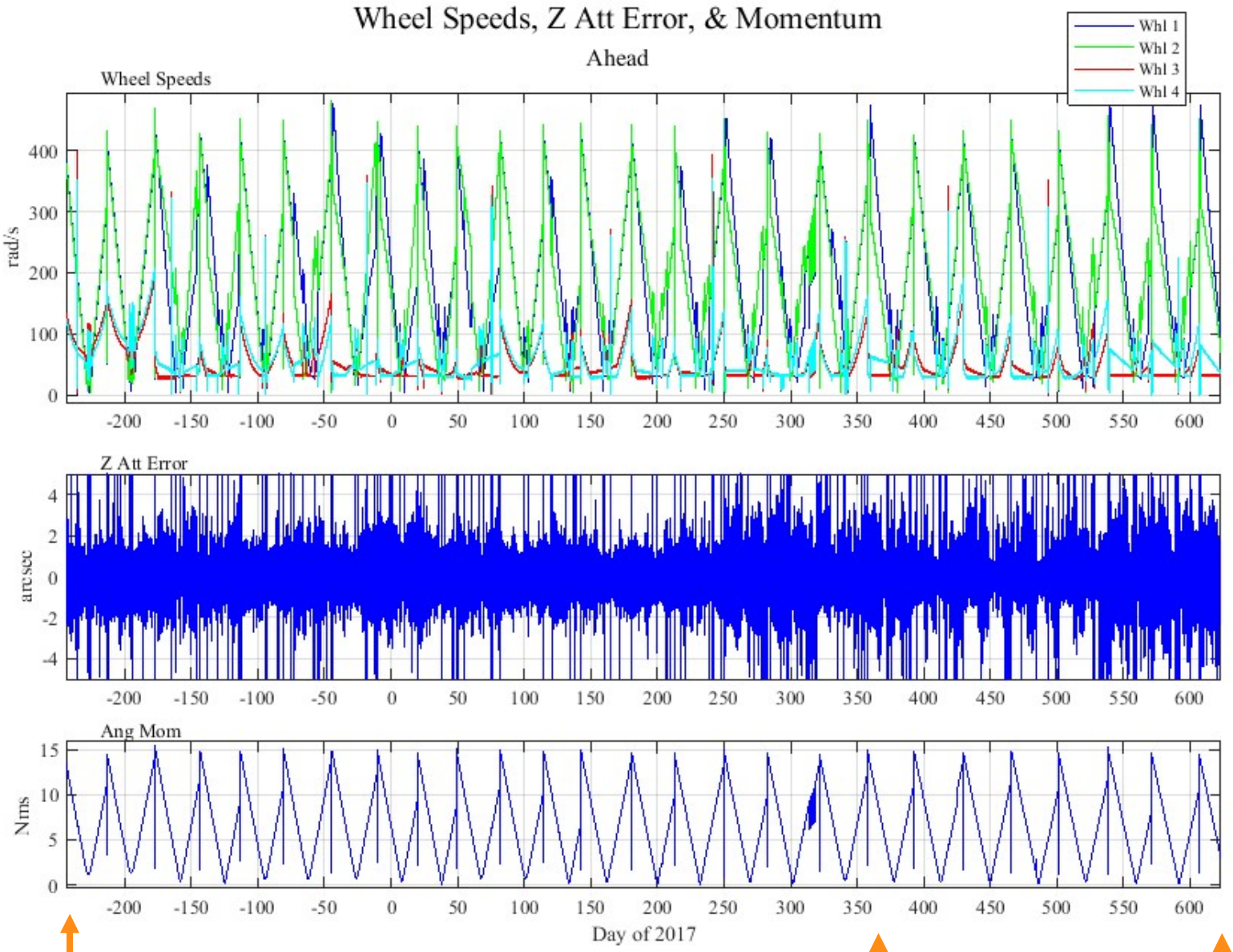
1 May 2016 – 14 Sep 2018

(2016:122 – 2018:257)

Attitude Error

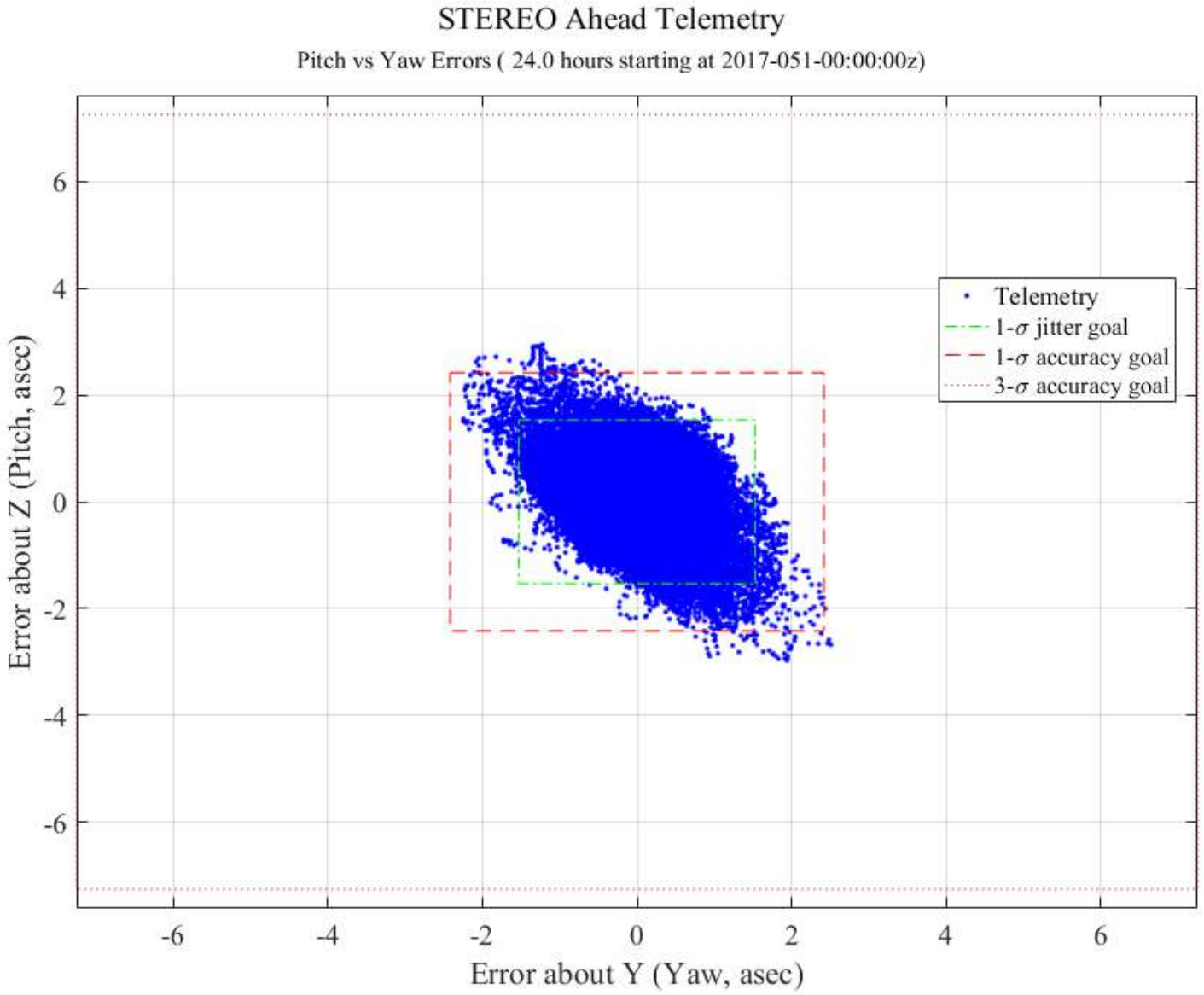


Space APL

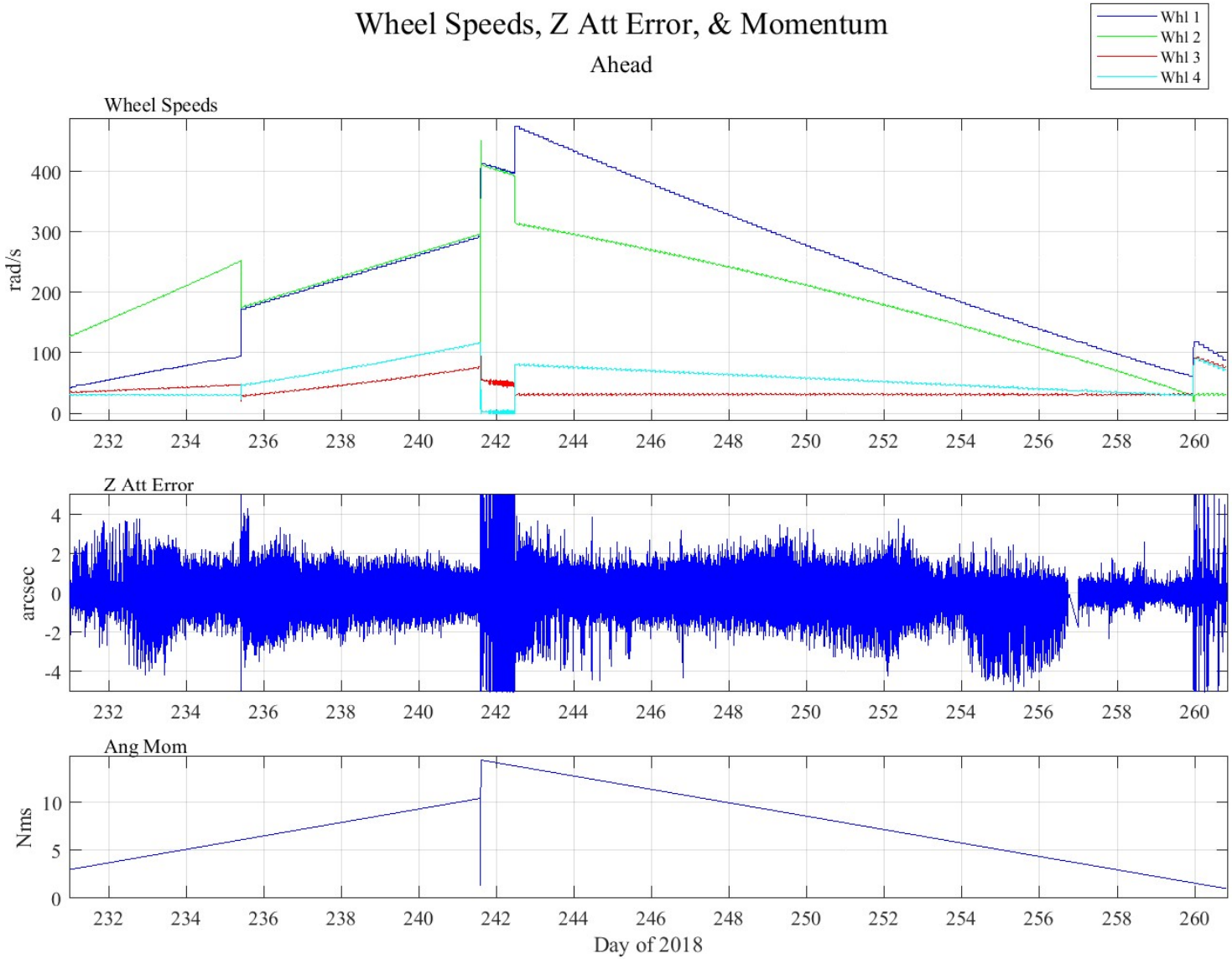

Wheel Speeds, Z Att Error, & Momentum
Ahead
Wheel Speeds
Whl 1
Whl 2
Whl 3
Whl 4
rad/s
Z Att Error
arcsec
Ang Mom
Nms
Day of 2017
1 May 2016
1 Jan 2018
14 Sep 2018

Space APL

Good Fine Pointing Example
2017-051

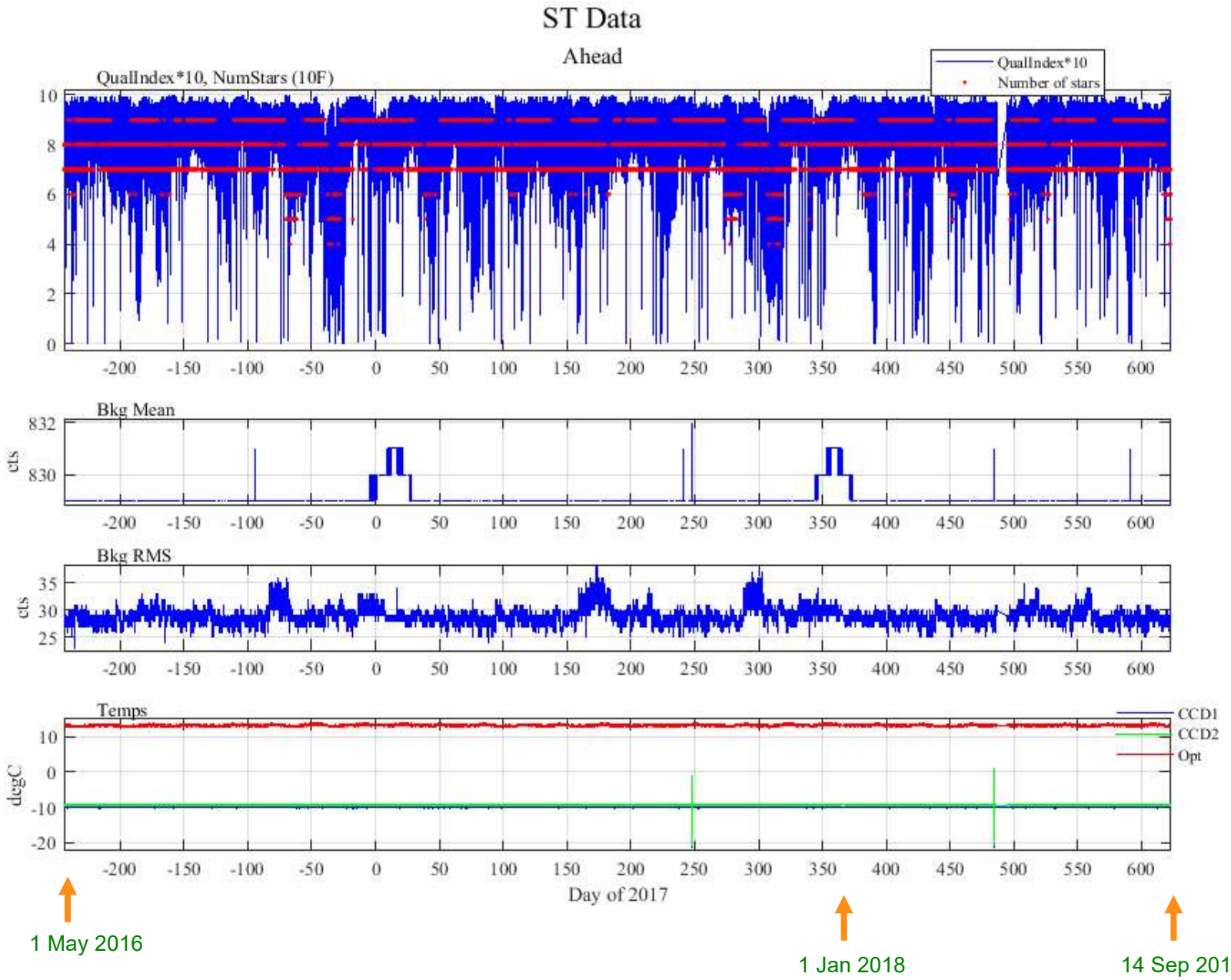


Most Recent 30-day Attitude Performance



ST Trend data

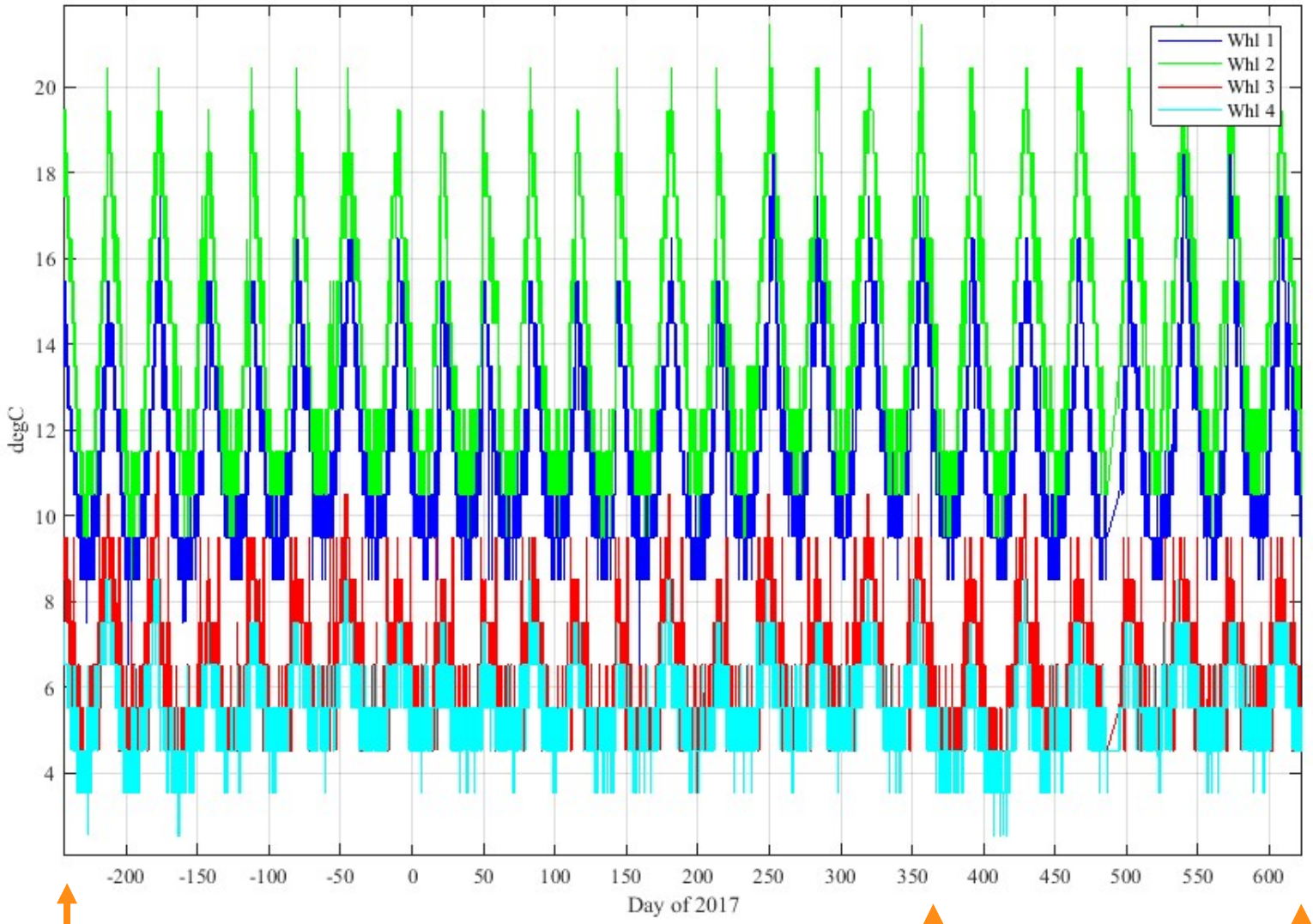
- **ST plots of Quality Index, Background, and temperatures follow.**
  - **Nothing significant to note.**


ST Data
Ahead
QualIndex*10, NumStars (10F)
QualIndex*10
Number of stars
Bkg Mean
cts
Bkg RMS
cts
Temps
CCD1
CCD2
Opt
degC
Day of 2017
1 May 2016
1 Jan 2018
14 Sep 2018

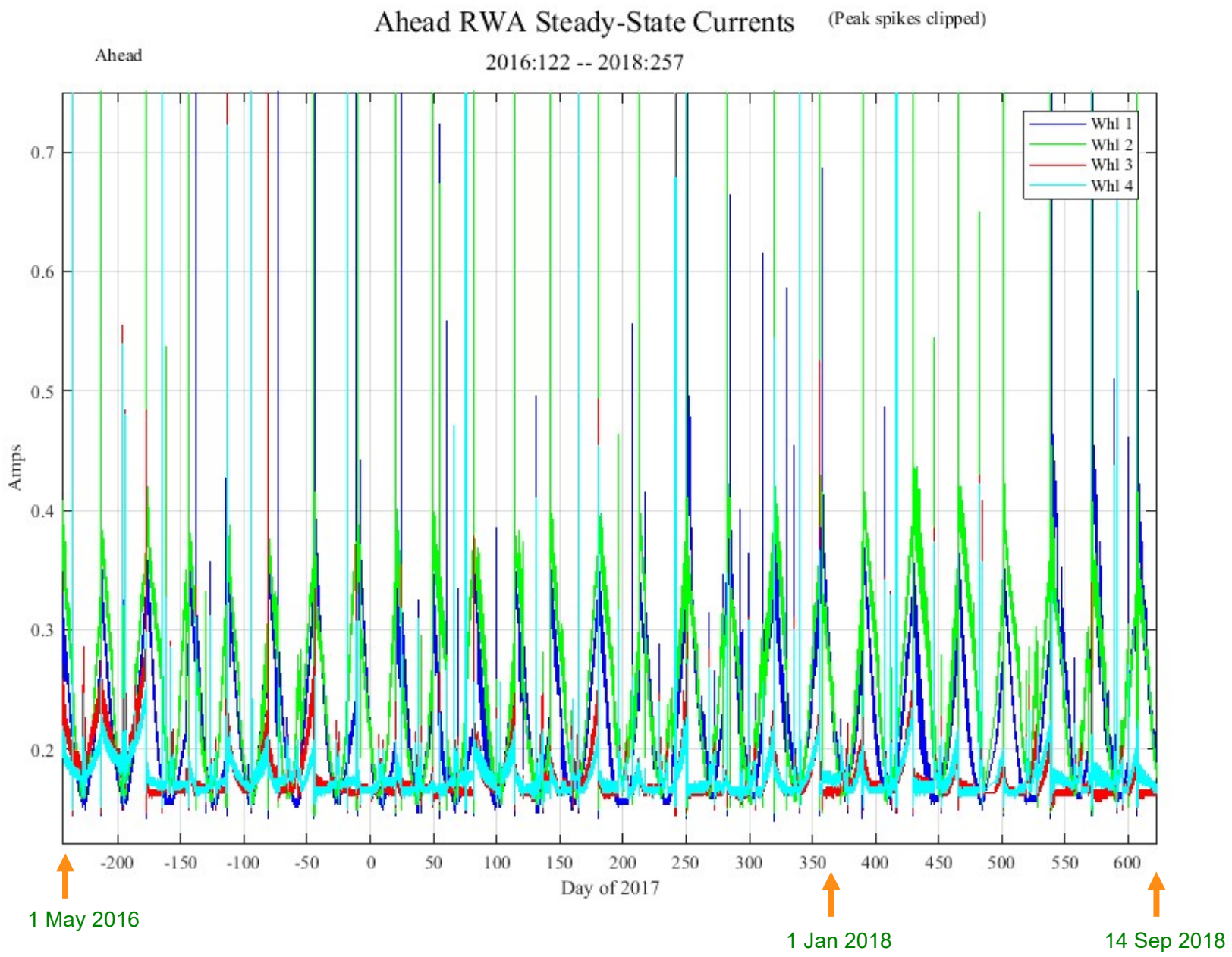
Space APL

Temperatures & Currents

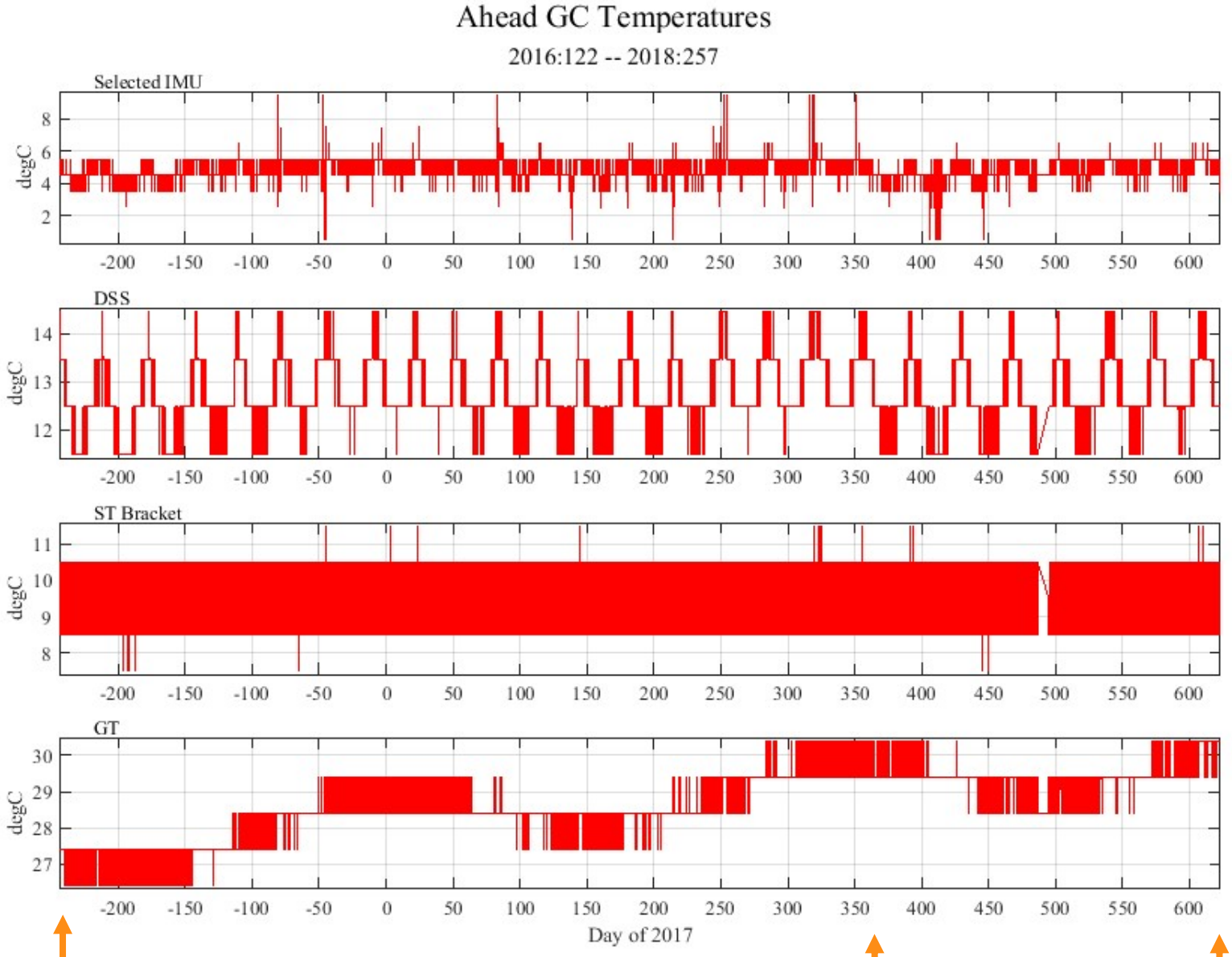
- **Summary –**
  - ***See following slides……***


Ahead RWA Temperatures
2016:122 -- 2018:257
Whl 1
Whl 2
Whl 3
Whl 4
degC
20
18
16
14
12
10
8
6
4
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
Day of 2017
1 May 2016
1 Jan 2018
14 Sep 2018

Space APL

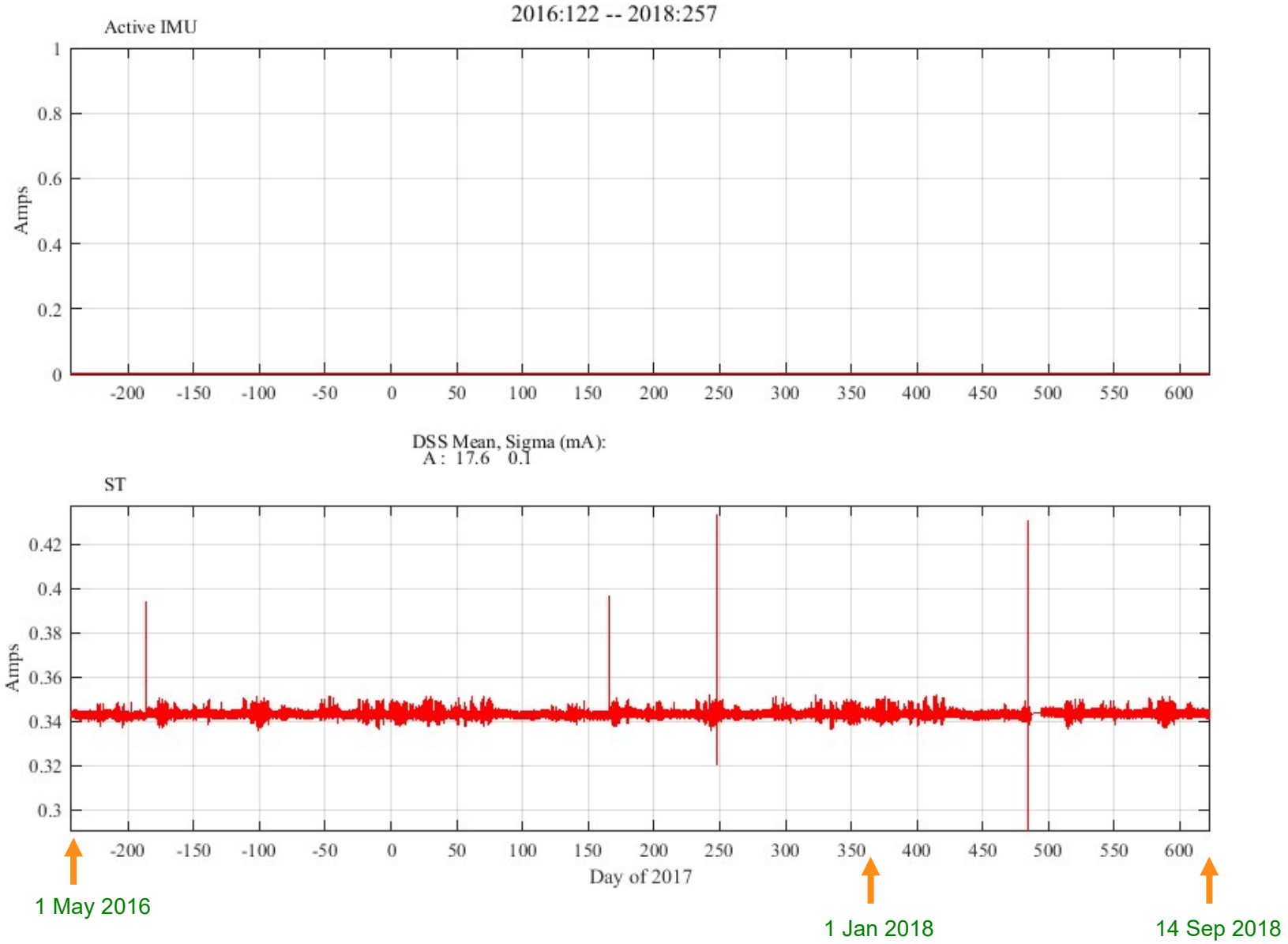

Ahead RWA Steady-State Currents
(Peak spikes clipped)
Ahead
2016:122 -- 2018:257
Whl 1
Whl 2
Whl 3
Whl 4
Amps
0.7
0.6
0.5
0.4
0.3
0.2
-200
-150
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
Day of 2017
1 May 2016
1 Jan 2018
14 Sep 2018

Space APL


Ahead GC Temperatures
2016:122 -- 2018:257
Selected IMU
DSS
ST Bracket
GT
degC
Day of 2017
1 May 2016
1 Jan 2018
14 Sep 2018

Space APL

Ahead GC Currents



Space APL

Anomalies

- **ST-A-2197: Fine-Pointing Losses & Increase Roll Jitter Post Solar Conjunction**
  - **Opened 2015-Nov-04**
  - **Has become a catch-all for fine-pointing problems post-conjunction**
  - **Initially opened upon SECCHI complaint of increased roll jitter post-conjunction**
  - **Status: Open**

Anomalies

- **ST-A-2198: Ahead Wheel Speed Correction Failure**
  - **Opened 2016-Feb-25**
  - **Wheel speed avoidance algorithm failed to converge on a solution (three times) resulting in 2 wheels operating at or near zero for a prolonged period of time**
    - **Attitude motion greatly degraded as G&C requested torque commands were not being delivered as desired due to wheel stiction and lubricant distribution effects**
  - **Appears to occur when two wheels are at or very near the avoidance band on opposite sides and the troublesome time was at the simultaneous speed crossover for the pair of wheels**
    - **Avoidance is only run once every three hours so could result in prolonged periods with the wheels operating at or near zero speed**
  - **Status: Monitor**

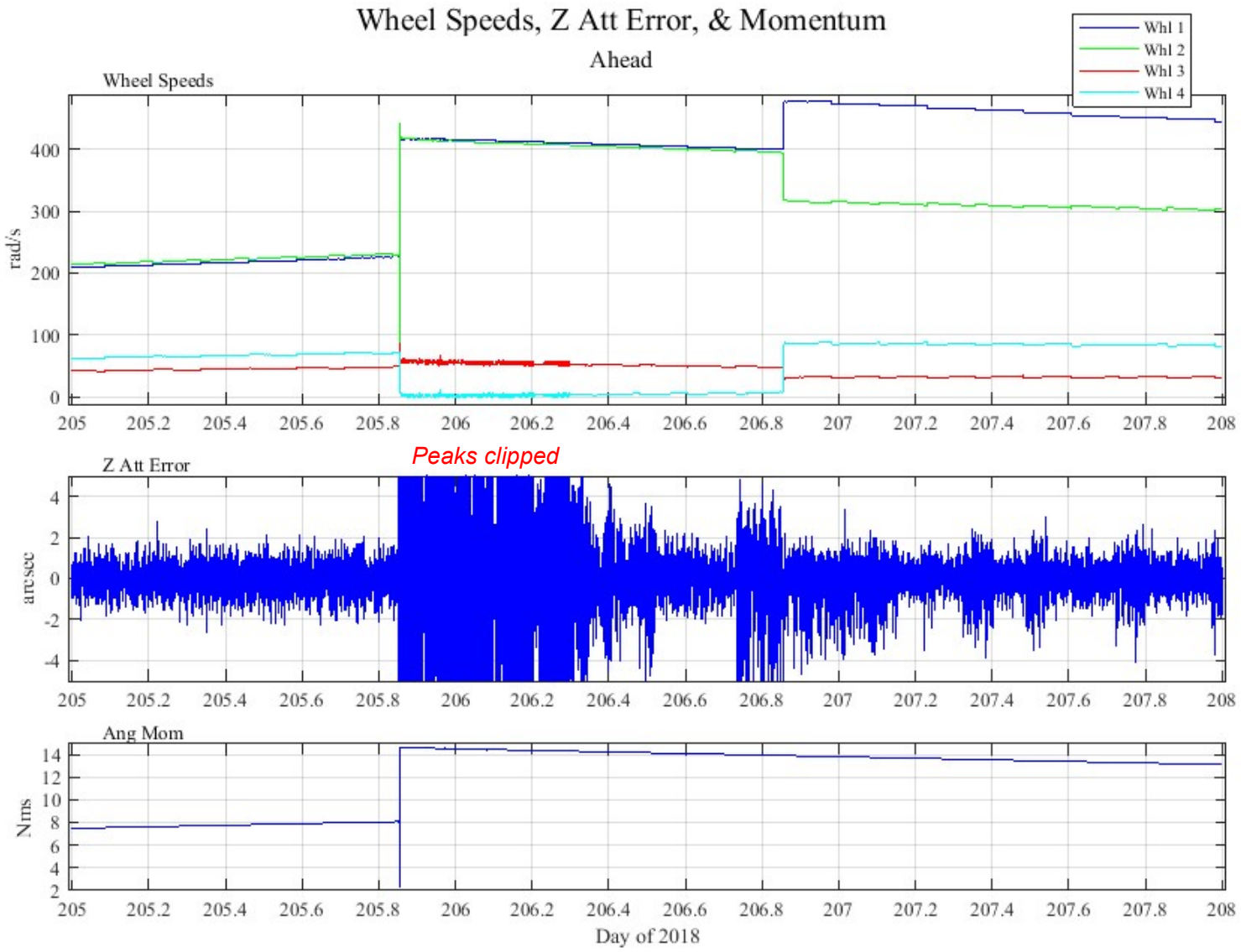
Loss of Fine Pointing Events

- **Noisy attitude motion causes an intermittent loss of Fine Pointing**
  - Ignoring momentum dumps, calibration maneuvers, loss of ST, wheel zero-speed crossings, etc.
- **Reasons:**
  - Wheel Speed Avoidance convergence failures
    - Note: WSA currently runs every 3 hours
  - Low wheel speeds (One or more wheels running for a prolonged period at or near the zero-speed avoidance threshold)
- **Occurrences:**
  - 18 May 2016 (doy 139) – Duration ~139-1030z – 139-2230z
  - 23 Dec 2016 (doy 358) – Duration ~358-0934z – 358-1234z
  - 31 Dec 2016 (doy 366) – Duration ~366-1558z – 366-2158z
  - 23 Feb 2017 (doy54) – Duration ~054-1933z – 054-2234z
  - 7 Mar 2017 (doy 066) – Duration ~066-1033z – 066-1033z
  - 10 Mar 2017 (doy 069) – Duration ~069-1033z – 069-1033z
  - 30 Apr 2017 (doy 120) – Duration ~120-0703z – 121-0403z
  - 19 Oct 2017 (doy 292) – Duration ~292-2104z – 294-1521z
  - 7 Jan 2018 (doy 007) – Duration ~007-1004z – 008-0724z
  - 11 Jul 2018 (doy 192) – Duration ~192-0204z – 192-1304z
  - 24 Jul 2018 (doy 205) – Following Momentum Dump; duration ~205-2030z – 206-2034z
  - 12 Aug 2018 (doy 224) – Duration ~224-0233z – 226-0349z

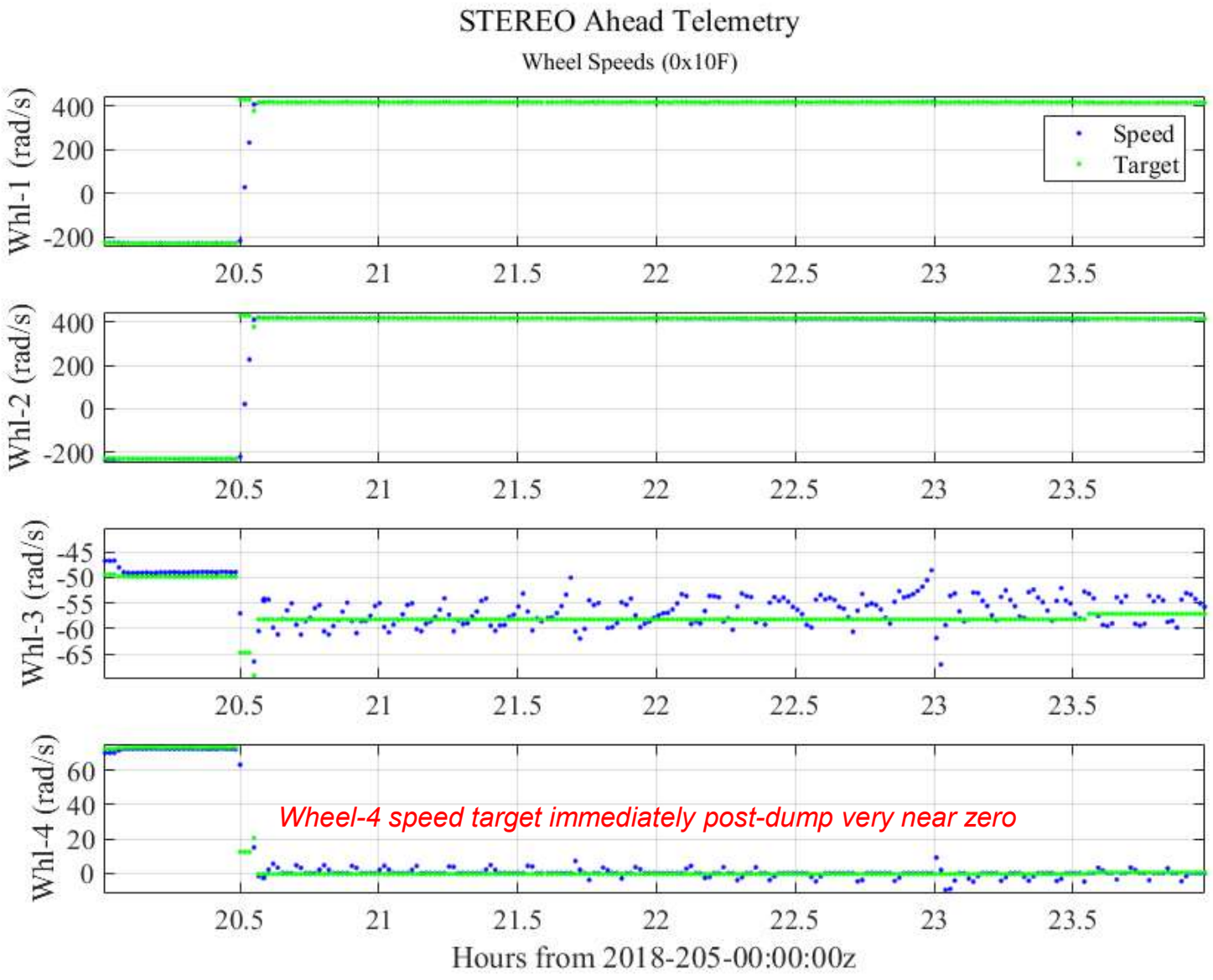
Fine Pointing Anomaly
2018-205 & 206 (Post-Momentum Dump)

- Following the momentum dump at 2018-205-2030z (111th Momentum Dump on Ahead), pointing performance was poor as wheel-4 was at a very low speed (well below the avoidance threshold).
- Wheel Speed Avoidance (WSA) apparently set a target wheel speed near zero for wheel-4 post-dump for several WSA cycles (targets are recomputed every 3-hours).
- Preliminary suspicion is that the wheel-speed target filter may be the cause along with the momentum state.
  - Still under investigation
  - Potential mitigations:
    - Increase the filter bandwidth
    - Decrease the WSA cycle time post-dump

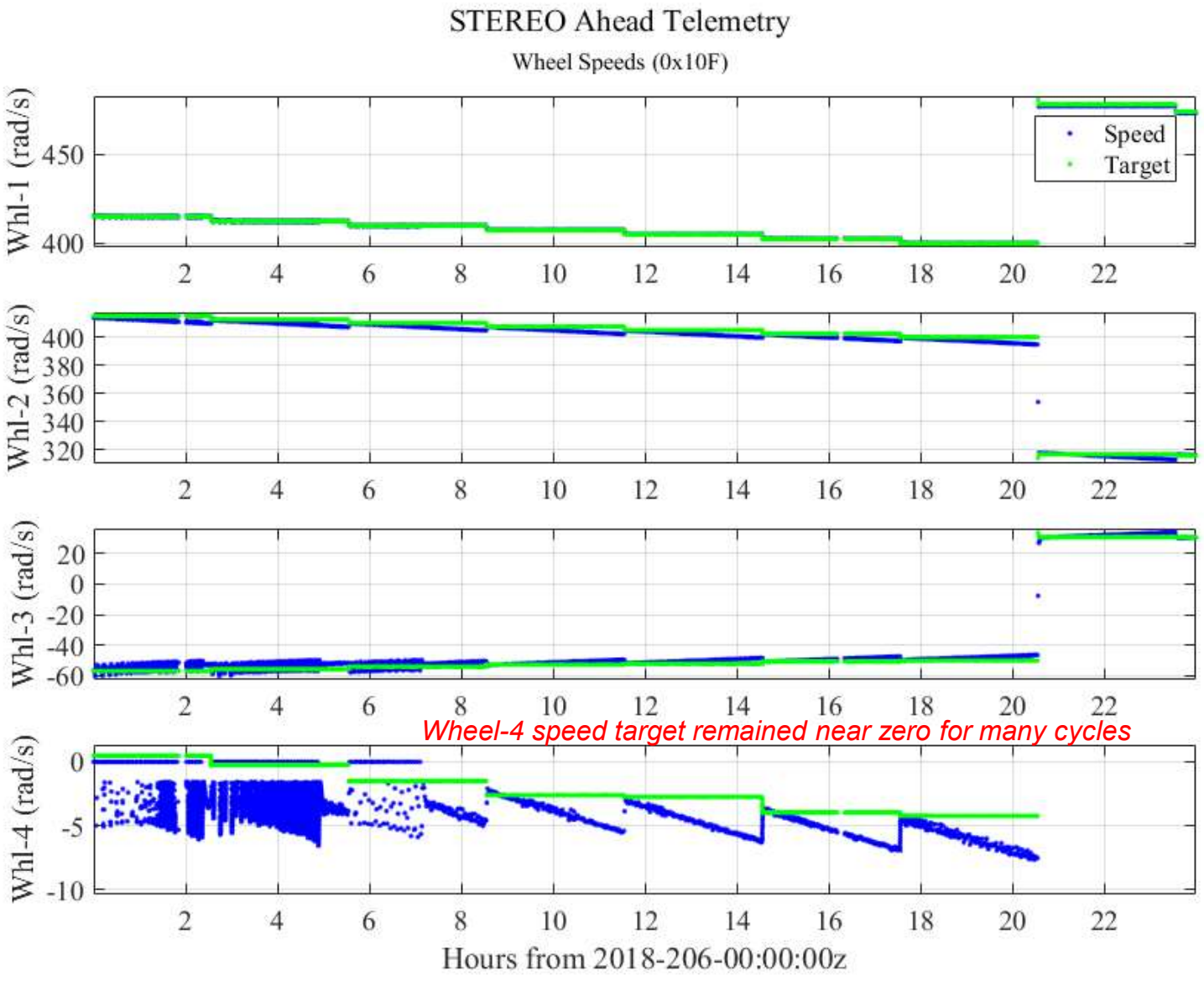
Fine Pointing Anomaly
2018-205 & 206 (Post-Momentum Dump)



Fine Pointing Anomaly
2018-205 & 206 (Post-Momentum Dump)

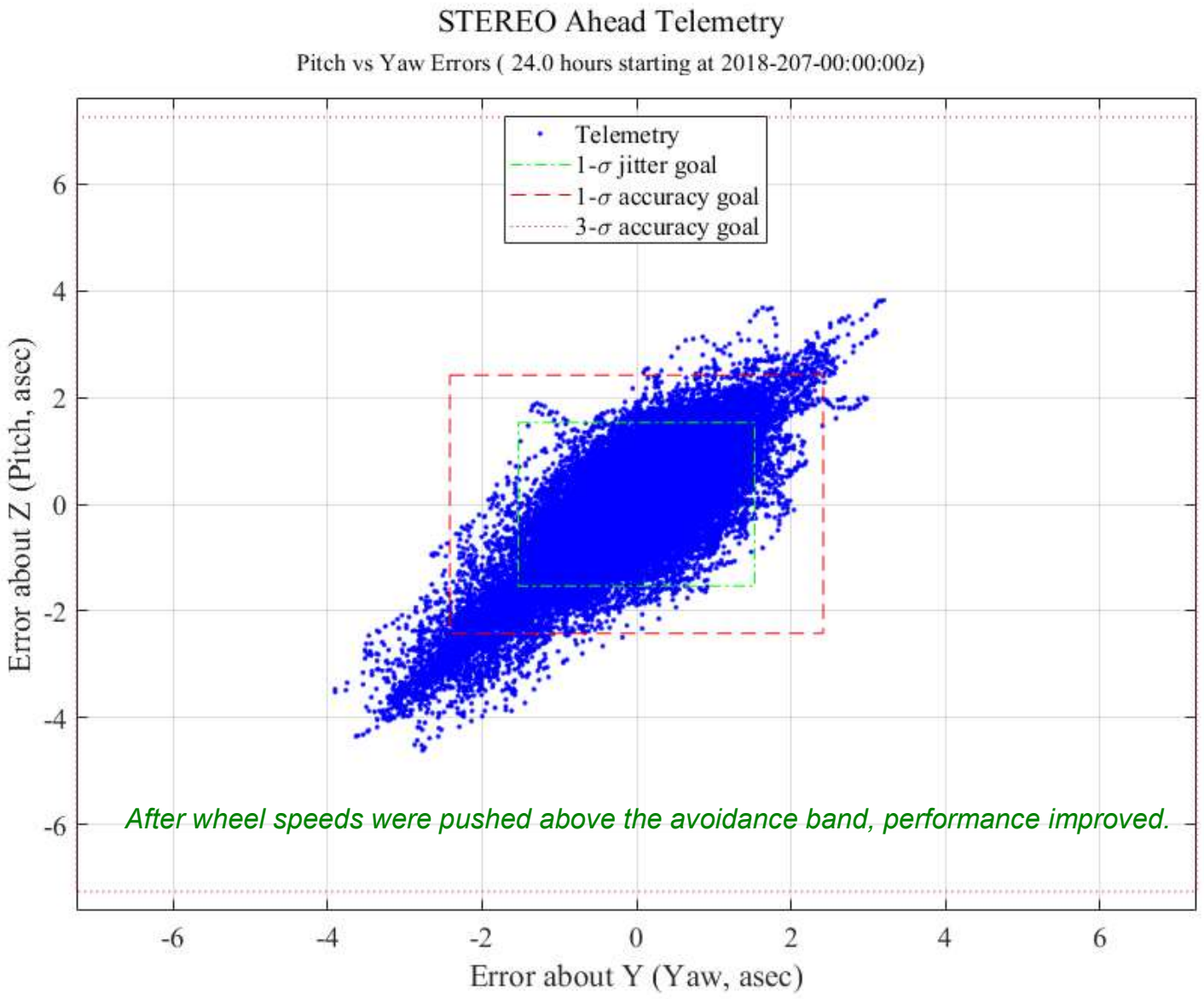


Fine Pointing Anomaly
2018-205 & 206 (Post-Momentum Dump)



Wheel-4 speed target remained near zero for many cycles

Fine Pointing Anomaly
2018-205 & 206 (Post-Momentum Dump)

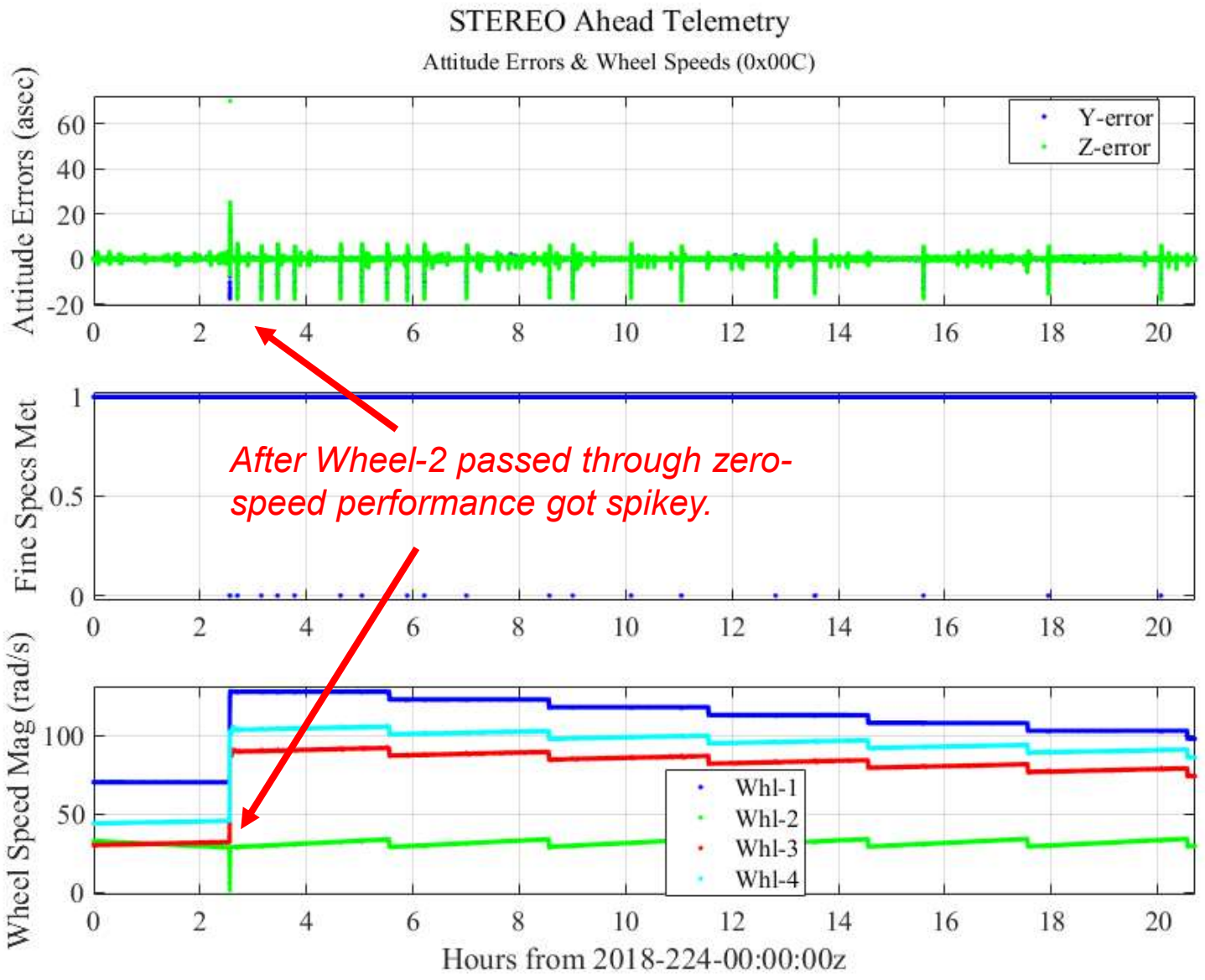


After wheel speeds were pushed above the avoidance band, performance improved.

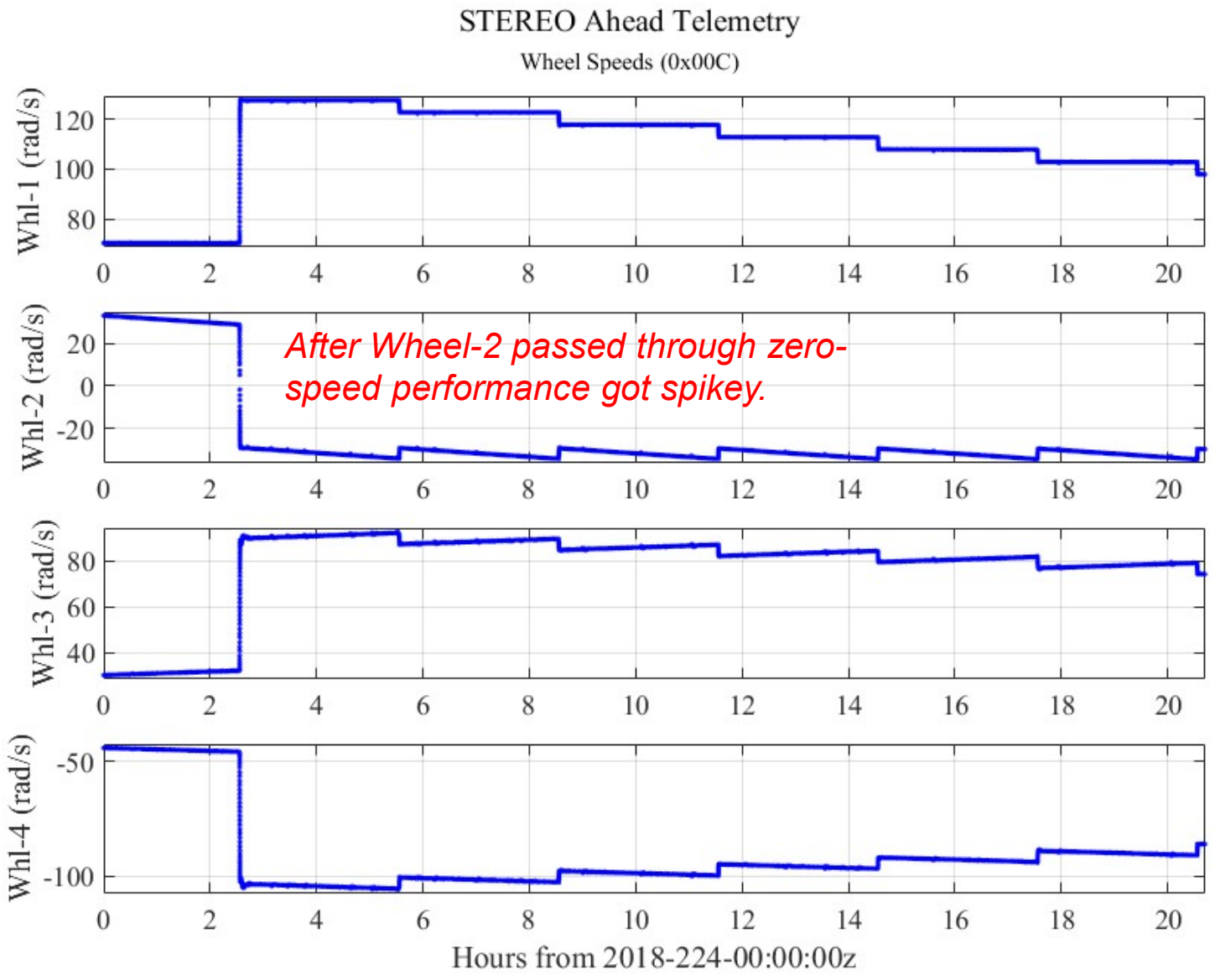
Fine Pointing Anomaly
2018-224

- On day 224, pointing performance degraded following a wheel passing through zero speed
- Attitude got “spikey”
- Suspicion is bearing lubricant distribution problem after wheel stopped
- Seemed to clear up after time and when wheel was eventually able to be commanded to a higher wheel speed

Fine Pointing Anomaly
2018-224



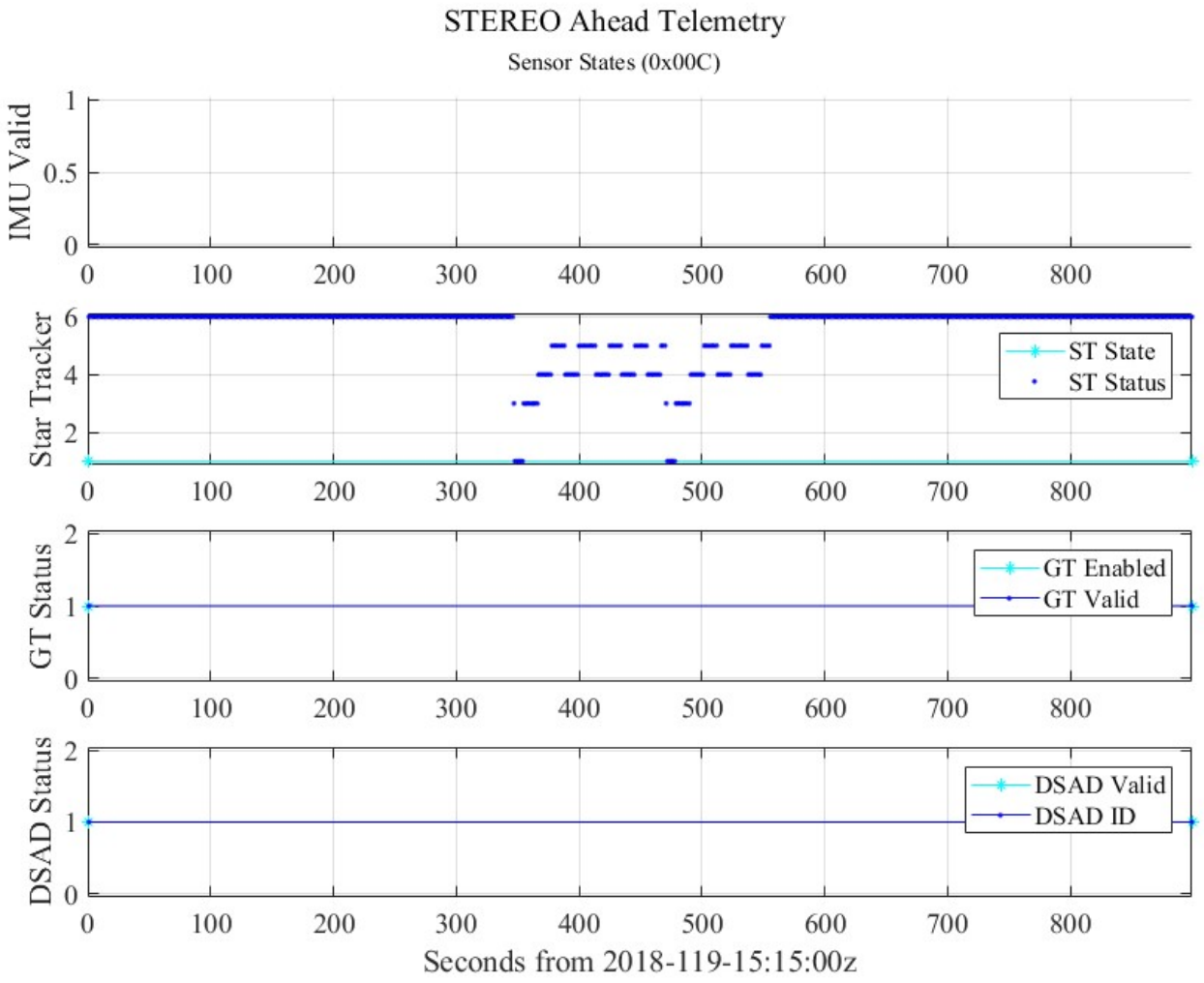
Fine Pointing Anomaly
2018-224



PFRs

- **ST-P-311: Ahead ST Reset & did not promote to AAD mode.**
  - **Status: Monitor (Opened 2010.01.27)**
  - **6th occurrence (since 2010) on 2017-247-11:32:40z**
    - **Successfully promoted to AAD mode 2017-247-11:32:52z**
    - **Reset cause: "CPU Error"**
    - **0.4° roll error and loss of roll-rate knowledge resulted in ~85 seconds of loss of fine pointing**
  - **7th occurrence on 2018-119-15:20:46z**
    - **Actually 2 resets in succession:**
      - **First @ ~15:20:46z**
      - **2nd commanded by autonomy (soft reset) @ 15:22:48z**
    - **Successfully promoted to AAD mode 15:24:01z**
    - **1st reset cause: "CPU Error"**
    - **1.2 ° roll error and loss of roll-rate knowledge resulted in ~6.2 minutes of loss of fine pointing**

Ahead ST Reset
2018-119



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Things to do…..

- **To improve system robustness:**
  - **Evaluate no-IMU performance – *On-going***
    - **Can momentum dumps be performed sans MIMU? ✓**
    - **What parameters need to be tuned for gyro-less operation? – *On-going***
  - **In the works: Adjusting Wheel Speed Avoidance parameters to improve robustness**
    - **Recent momentum dumps have resulted in WSA targeting wheel speeds within the avoidance band. Believed to be due to the target speed filter (that cannot be reset)**
    - **Potential mitigations include shortening the WSA computation time from 3-hours to a short period following a dump and increasing the filter bandwidth to speed convergence**

- **Continue to monitor performance and tweak parameters, as necessary.**

STEREO Subsystem Long Term Telemetry Assessment

Autonomy & Flight-Software

19-Sept-2018

Versions:

18-May-2018 – Initial (K.Balon)
22-May-2018 – Refined following CPU-utilization plot review.
24-May-2018 – Added routine MOPS activities: Mom-Dumps & SECCHI-cal rolls.
23-July-2018 – minor updates
3-Aug-2018 – update to new date

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Overview

- **Period covered:**
  1-May-2016 (day-2016-122) through
  30-June-2018 (day-2018-181) (AHEAD only)

- **Autonomy**
  - **Review: Definition-of-Terms**
  - **Autonomy-Release Summary**
  - **Current status**

- **Flight-Software**
  - **Current On-board FSW-Configuration / Releases / Patches**
  - **CPU-utilization: Conjunction → Post-Conjunction**
    - **Tied to: Downlink-rate**
  - **FSW Monitoring Activity**

- **Backup Items**
  - **Autonomy Enhancement Details**
    - **AUT-2.3.11 thru RGO-2.3.12 thru Conjunction thru NGO-2.3.19 Post-Conj**

Extended-Mission Evolution / Useful Terms:

- **RGO == Reduced Gyro Operations**
  - Star-Tracker became Primary G&C-sensor (~Aug-2013)
  - Limited-IMU-usage for Mission-Ops –and– Fault-Protection
- **Solar-Conjunction Operations**
  - Builds upon RGO
  - No Ground-Contacts / HCLT-resets (24-Mar-2015 thru 7-July-2015)
  - HGA-side-lobe / reduced tlm-rate comm; (~Aug-2014 – 30-Dec-2015)
  - Autonomy: Keep S/C safe during Solar-Conjunction & HCLT-Resets
- **NGO == No Gyro Operations**
  - **Builds upon RGO / Solar-Conjunction-Ops**
  - **Routine-Science & Ground-Contacts ~~resume~~**
  - **No-IMU-usage for Routine-Mission-Ops**
  - **Any-remaining-IMU-usage is reserved for: Fault-Protection**

Autonomy

Autonomy Releases – Extended Mission

Aut Version	Date	S/C	IMU usage	Motivation / Reason / Comment
AUT-2.3.11	Aug-2009	Both / Identical	IMU(s) Primary along w/ ST	**Nominal-Ops**
RGO-2.3.12	Aug-2013	AHEAD	Good-IMU Introduced (Ahead)	Minimize usage of remaining 'good'-IMU
RGO-2.3.13	Feb-2014	Both	Good-IMU Introduced (Behind)	IMU specific by S/C
RGO-2.3.14	Jun-2014	Both	IMU for both Ops and FP	IMU-on for Mom-Dumps
RGO-2.3.15	Aug-2014	Both (last on Behind)	IMU for both Ops and FP	Preserve-IMU-life rule added
RGO-2.3.16	23-Oct-14	AHEAD	IMU for both Ops and FP	IMU-fault protection (bad data used as good)
RGO-2.3.17	9-Jan-15	AHEAD	**Solar-Conjunction Ops** Minimize IMU-usage	(final tweaks before Solar-Conjunction)
NGO-2.3.18	2-Dec-15	AHEAD	**IMU-usage for FP-only**	**Post-Conjunction NGO-ops**
NGO-2.3.19	12-May-16 **(2-Jun-16 to EEPROM)**	AHEAD	IMU-usage for FP-only	**Post-Conjunction NGO-ops** (introduce protections observed from Sol-Conj)

Current Autonomy: NGO-2.3.19:
No new AUT releases since last (2016) Assessment review.

STEREO Autonomy Evolution:
Launch/Nominal Ops → RGO → Solar-Conjunction → NGO

Autonomy Release Evolution (Time)

	Aut Usage:	**Nominal-Ops Autonomy**		**RGO-Autonomy**				**RGO-Aut for Solar Conjunction**			**Improved RGO-Aut for Solar Conjunction**							**Improved Aut for NGO/Post-Conjunction**					
	Comments:	Autonomy baseline IMU-1_A as 'primary'		Supports minimal usage of IMU. Shifts to concept of: 'good-IMU'				'Tuned' for Solar-Conjunction Ops. Continues concept of: 'good-IMU'			Solar-Conjunction Ops. 'Tuned' following BEHIND-anomaly. Autonomy improvements for good-IMU gyro failures. Continues concept of: 'good-IMU'.							Post-Conjunction No Gyro Ops. 'Tuned' following Solar-Conjunction Distinguishes btwn Autonomous- and Routine-Mom-Dumps					
	Release:	**AUT-2.3.11**	AHEAD-IMU-A fails Apr-2007;AHEAD-IMU-B preserve-life-of 18-Sept-2013	**RGO-AHEAD-2.3.12**	BEHIND-IMU-A preserve-life-of 28-Oct-2012; BEHIND-IMU-B fails 5-Jan-2014	**RGO-2.3.13 (Both S/C)**	Plan for Solar-Conjunction (Protect HGA from heat.)	**RGO-2.3.14 (Both S/C)**	**RGO-2.3.15 (Both S/C)**	(remaining) BEHIND-IMU-A fails 1-Oct-2014	**RGO-2.3.16 (AHEAD-only)**	Improve ST-performance (reduce TEC-temperature)	**RGO-2.3.17 (AHEAD-only)**	Solar-Conjunction (March->July-2015)				**RGO-2.3.18 (AHEAD-only)**		**RGO-2.3.19 (AHEAD-only)**			
	Date:	Aug-2009		Aug-2013		Feb-2014		June-2014	Aug-2014		**23-Oct-2014**		9-Jan-2015					Released: 13-Nov-2015 Operations:2-Dec-2015		Released: 14-Apr-2015 Operations: TBD			
	Target S/C:	Either (agnostic)		AHEAD		Both S/C																		
	Target IMU:	Either (agnostic)		IMU-B(2)		'Good-IMU'																		
	Aut Lead:	G.Cancro --> M.Trela -->J.Thomas (no releases)		T.A.Hill		K.Balon		K.Balon	K.Balon		K.Balon		K.Balon					K.Balon		K.Balon			
Target S/C:																								
AHEAD	Release: Good IMU:	AUT-2.3.11 Primary-IMU (IMU-1_A)		RGO-AHEAD-2.3.12 IMU-2_B		Never Loaded to AHEAD		RGO-AHEAD-2.3.14 IMU-2_B	RGO-AHEAD-2.3.15 IMU-2_B		RGO-AHEAD-2.3.16 IMU-2_B		RGO-AHEAD-2.3.17 IMU-2_B					NGO-AHEAD-2.3.18 IMU-2_B		NGO-AHEAD-2.3.19 IMU-2_B			
BEHIND	Release:	AUT-2.3.11		na		RGO-BEHIND-2.3.13		RGO-BEHIND-2.3.14	RGO-BEHIND-2.3.15		na		na					na		na			
	Mods:							**Primarily Disables Conflicting Rules**			**Improves Autonomy for remaining-IMU individual gyro-axis failure(s)**			-->				**Improves Autonomy for Momentum Dumps**					
								Automatically Turns-on IMU for Mom-Dumps		-->	Automatically Turns-on IMU for Mom-Dumps			-->				Automatically Turns-on IMU for *Autonomous* Mom-Dumps; (IMU is off for routine-Mom-Dumps)					
									Optimizes IMU-life-preservation (rule-128)	-->	Optimizes IMU-life-preservation (rule-128)			-->				IMU on/off separted btwn Fault-Protection and MOPs including G&C-gains. (R127-IMUon/R128-IMUoff)					
											Re-enables **R124** in M148 to protect against failed gyro-axis/axes. GNC-FSW-patch-protection added as well)			-->				Continues **R124** and GNC-patch protections against failed gyro-axis/axes.					
													sCLT: 60hrs-->48hrs	(Ant Cycling)										
														Wheel #3 Overspeed						Wheels power cycled (corrects latched overspeed conditions)				
														DSAD/ST-Attitude				(short-fuse) R019/M124 (DSAD/ST goodness cross-check) lengthend from 30-secs to 2-minutes)					
													(long-fuse) R029/M067 (DSAD/ST goodness cross-check disabled); R028-offers-preferred-protection	sLVS-events (4)				(long-fuse) R029/M067 (DSAD/ST goodness cross-check disabled); R028-offers-preferred-protection		(long-fuse) new: R029/M067 (DSAD/ST goodness cross-check) (pre-sLVS / SA-power)			
						Improved IMU health checks (aut.mom.dumps)	-->	Improved IMU health checks (aut.mom.dumps)		-->	Improved IMU health checks (aut.mom.dumps)			-->				Continue IMU health checks (aut.mom.dumps)					
				Introduces RGO-rule-127: **Turn-on IMU when ST-unhealthy**			-->	RGO-rule-127: Turn-on IMU when ST-unhealthy		-->	RGO-rule-127: Turn-on IMU when ST-unhealthy (after 1-minute)			-->				RGO-rule-127: Turn-on IMU when ST-unhealthy (after **30**-minutes)		RGO-rule-127: Turn-on IMU when ST-unhealthy (after **30**-minutes, **debounced**)			
		Baseline Autonomy	-->				-->			-->		-->		-->										
	On-orbit:	Nomial-Ops Autonomy Operating since Aug-2009		**RGO-Logic Operating since Aug-2013**				**On-orbit Test: 6-July-14 --> 10-July-14**	**On-orbit Test: 27-Sept-14-->5-Oct-14** (ST-lazy; IMU-B X-gyro failure upon its pwr-up; loose contact.)		**No further S/C testing planned prior to Sol.Conj.**		**No further S/C testing planned prior to Sol.Conj.**										

Current Autonomy: NGO-2.3.19:
No new AUT releases since last (2016) Assessment review.

Space APL

Post Solar-Conjunction: MOP's Fault-Protection / Autonomy Event History

Autonomy Events for 2018 review period:

Start Date	Start Time (z) (YYYY-DOY-HHMM)	End Time (z) (YYYY-DOY-HHMM)	Event	Observatory	IMPACT	PLASTIC	SECCHI	SWAVES	C&DH	G&C	Power	Propulsion	RF	Thermal	Autonomy	1553 Errors	A/P Sides	Lost Fine Ptng	Lost Course Ptng	Remarks
12-May-2016	2016-133-1710		Observatory Load Autonomy Version 2.3.19 (RAM)	X											X					Loaded new autonomy rule 29/macro 67/compute telemetry 10 (Monitor For Low Solar Array Voltage); loaded updated autonomy rule 127 (new M-of-N); loaded updated macro 11 (added RW power cycle commands); all to RAM only at this time.
1-Jun-2016	2016-153-0606	2016-153-2300	SECCHI Reset (39) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
2-Jun-2016	2016-154-1535		Observatory Load Autonomy Version 2.3.19 (EEPROM)	X											X					Loaded new autonomy rule 29/macro 67/compute telemetry 10 (Monitor For Low Solar Array Voltage); loaded updated autonomy rule 127 (new M-of-N); loaded updated macro 11 (added RW power cycle commands); all to RAM only at this time.
9-Sep-2016	2016-253-0733	2016-254-2200	SECCHI Reset (40) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065. SECCHI's camera electroncs boxes did not come on as expected during the 253-2145 DSS-45 recovery effort; a CEB restart during the 254-1650z DSS-26 track resolved the issue; regular observations commenced at 254-2000z.
7-Oct-2016	2016-281-0737	2016-281-1852	SECCHI Reset (41) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
16-Oct-2016	2016-290-1905	2016-291-0000	SECCHI Reset (42) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
18-Feb-2017	2017-049-2227	2017-050-1400	SECCHI Reset (43) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
18-May-2017	2017-138-0058	2017-139-0300	SECCHI Reset (44) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
8-Jun-2017	2017-159-1925	2017-160-1700	SECCHI Reset (45) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
4-Sep-2017	2017-247-113238	2017-247-113257	Observatory Star Tracker Reset (6)	X						X					X			X	X	On day 247, the star tracker on STEREO Ahead reset at 11:32:38z. The star tracker was immediately promoted back to AAD mode by fault protection at 247-11:32:57z. Diagnostic data indicated the reset cause was due to a CPU Error, same as previous resets. With no rate data available, a 0.4 degree X-axis roll error occurred which resulted in the loss of fine pointing for a total of 85 seconds, from 11:32:44z
23-Oct-2017	2017-296-1932	2017-298-0000	SECCHI Reset (46) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
29-Jan-2018	2018-029-1120	2018-029-1634	SECCHI Reset (47) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
18-Mar-2018	2018-077-1201	2018-077-1600	SECCHI Reset (48) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
7-Apr-2018	2018-097-2129	2018-098-1300	SECCHI Reset (49) - Watchdog Timeout				X			X					X			X		Possible momentary loss of fine pointing due to loss of GT data; autonomy rule 126 fired. AR ST-A-2065.
29-Apr-2018	2018-119-152046	2018-119-152401	Observatory Star Tracker Reset (7)	X						X					X			X	X	On day 119, the star tracker failed to find a solution at 15:20:46z. Fault protection soft reset the star tracker and promoted it back to AAD mode 15:24:01z. Diagnostic data indicated the reset cause was due to a CPU Error, which has occurred previously. With no X-axis rate data available to G&C, a 1.2 degree X-axis roll error occurred which resulted in the loss of fine pointing for a total of 6.2 minutes, from 15:22:05z through 15:28:16z. This was the 7th star tracker reset on the Ahead observatory since launch.

- **Summary – NGO-2.3.19 serving quite well…**
- **No FP-events not seen before:**
  - **Rule-126 firings due to SECCHI-resets/loss-of-fine-pointing.**
  - **AUT rule-firings to promote ST following (two) ST-resets due to self-detected ST-CPU-Errors.**

Summary - Autonomy

- **STEREO's Autonomy has served well; continues to do so…**
  - **From: Primary-Ops**
    - **IMUs primary & redundant**
  - **To: Reduce-Gyro-Ops**
    - **ST primary-G&C-sensor augmented-by-remaining good-IMU**
  - **Throughout: Solar-Conjunction**
    - **Out-of-contact ~4-months, w/ HGA-thermal and Comm challenges**
  - **And currently under Post-Conjunction "No"-Gyro-Ops (NGO):**
    - **Anticipating next concerns / risks / failures?:**
      - **Wheels**
      - **Complete-loss of IMU**
      - **Addresses potential LVS issue(s) sooner**
      - **Refer to the 15-June-2016 information in Backup-section for details.**

Flight-Software

Flight-Software

- **CDH-CPU:**
  - **EA-bypass (AHEAD) switch thrown 23-Jun-2014**
    - **EA-mode Deprecated**
    - **→ CDH-App and CDH Autonomy**
  - **CDH Version-3.2.4 uploaded 29-July-2014**
    - **Included CDH-patches that were already flying on CDH-B-3.2.3**
    - **CDH-3.2.4 loaded: because of reoccurring HCLT-resets during solar-conjunction**
- **GC-CPU:**
  - **GNC Version-3.2.6 – flying since 30-Jun-2009 (Ahead)**
    - **Activated on Ahead on 4-Aug-2009 with a reset to EA and subsequent recovery.**
    - **Single GNC-Patch - Guard against bad-IMU-data flowing into G&C-control-algorithm**
      - **CR-6864 - Block Bad IMU Data**
      - **Applied 27-Jan-2015**
      - **Re-applied via Auto-Exec-Macro (MOPs-Perm-1.1.17) upon any reboot**

GNC-Patch

- **Patch applied AHEAD ~RGO-2.3.16**

Current GNC- 3.2.6 Patch			
Patch	**Description**	**Delivered to Mops / Spacecraft**	**Comment**
CR-6864	Block bad IMU data from getting into (G&C) algorithm	1/27/2015; in MOPs-Perm-1.1.27	Patch works in conjunction w/ Fault-Protection Rules R124 (long-fuse) and R018(short-fuse); to prevent invalid IMU-data from prorogating to G&C

Current Object Releases for Post-Solar-Conjunction (Ahead):

On-board Configuration Items:

	EEPROM-1	EEPROM-2
CDH Flight Software	cdh_b_3_2_4 (no change)	cdh_b_3_2_4 (no change)
G&C Software **+ RAM-Patch**	gnc_b_3_2_6 (no change)	gnc_b_3_2_6 (no change)
Fault Protection	**aut_src_RGO_AHEAD_2-3-19-Release** (no change)	**aut_src_RGO_AHEAD_2-3-19-Release** (no change)
Data Handling	dh_1_1_11 (no change)	dh_1_1_11 (no change)
G&C Parameters	gnc-alg_1_3_5 was @ last review: gnc-alg_1_3_4	gnc-alg_1_3_5 was @ last review: gnc-alg_1_3_4
Power	power_1_0_3 (no change)	power_1_0_3 (no change)
MOps Perm	mops-perm_1_1_30 was @ last review: mops-perm_1_1_29	mops-perm_1_1_30 was @ last review: mops-perm_1_1_29

STEREO CDH -Nominal CPU Utilization

- Assessment data for AHEAD S/C reviewed:
  - Time period reviewed:
    - 2016-day-122 (1-May-2016) through 2018-day-181 (30-Jun-2018) :: for this 2018 review
  - G&C utilization is nominally ~51%; ~59%-peak
  - C&DH utilization – tied mainly to downlink-rate (see below):

STEREO CDH CPU Utilization – varies with Downlink Rate

Downlink rate (Dish)	CPU Utilization
-	~40% CPU
720 kbps (70m)	80% CPU ~85% peaks during SSR playback
480 kbps (70m)	70% CPU
360 kbps (34m)	60% CPU
240 kbps (34m)	55% CPU
160 kbps (34m)	45% CPU
120 kbps (34m)	~43% CPU

Representative Ahead CPU Performance - 2016 – 2018
Routine Downlinks

Begin Period: 23/25-Aug-2016 (Day-236/237/238)
Out-of-Contact – ~40% CPU
240kbps (34m) contacts - ~55% CPU
Occasional-swing to ~100%-CPU

Report Start: 8/24/2016 11:39:17 AM Record Number 2363
Report End:

Executive Summary: STA, DSS-26, 2016-237:1530-1855 - Weekly UT command load., Undo Events for DOY 238 change, Time EEProm Update

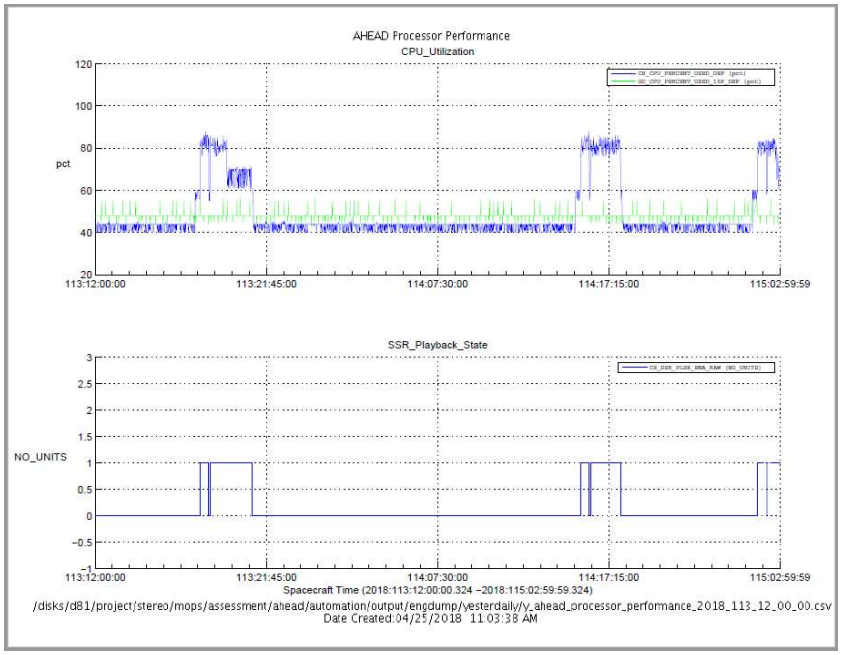
1st Shift Activities

Test Director: George Chiu Electrical Tech:
Test Conductor: Matthew Cox Mechanical Tech:

Shift 1 Activities
1530z - BOT
1542z - Started UT command load
1629z Finished UT CMD Load
1631z Sent Undo CMDs for DOY 238 track change
1636z Started Time Eeprom Update
1710z Finished Time EEPRom Update
1714z Went Unattended
1855z - EOT

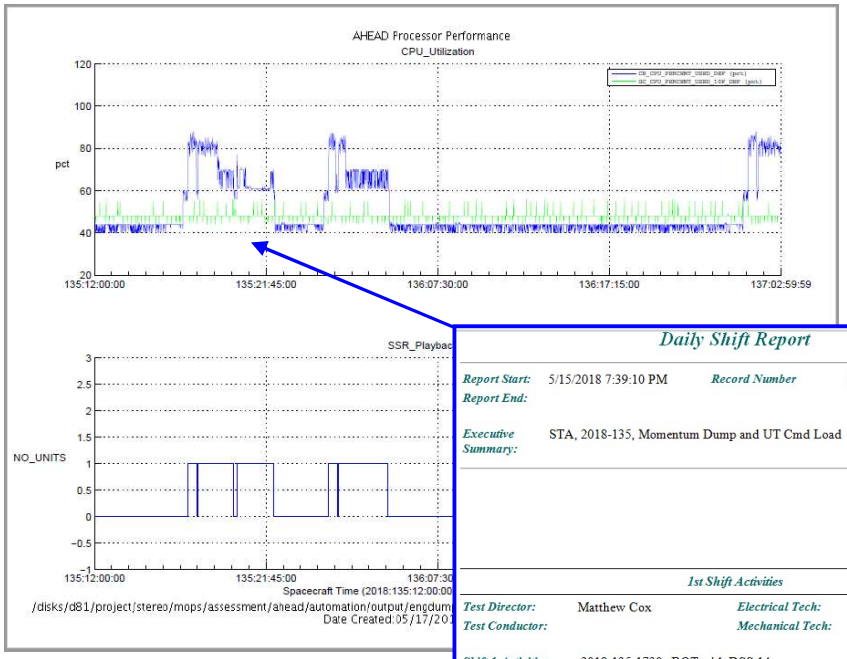
Note: Brief ~100% CPU during commanding.

End Period: 23/25-Apr-2018 (Day-113/115)
720kbps (70m) contacts – ~80% CPU



Representative Ahead CPU Performance - 2016 – 2018
Momentum Dumps & SECCHI-cal Rotations

109th Mom-Dump: 15-May-2018 (Day-137)
720kbps (70m) contact – ~80% CPU



Daily Shift Report

Report Start:	5/15/2018 7:39:10 PM	*Record Number*	2558
Report End:			
Executive Summary:	STA, 2018-135, Momentum Dump and UT Cmd Load		

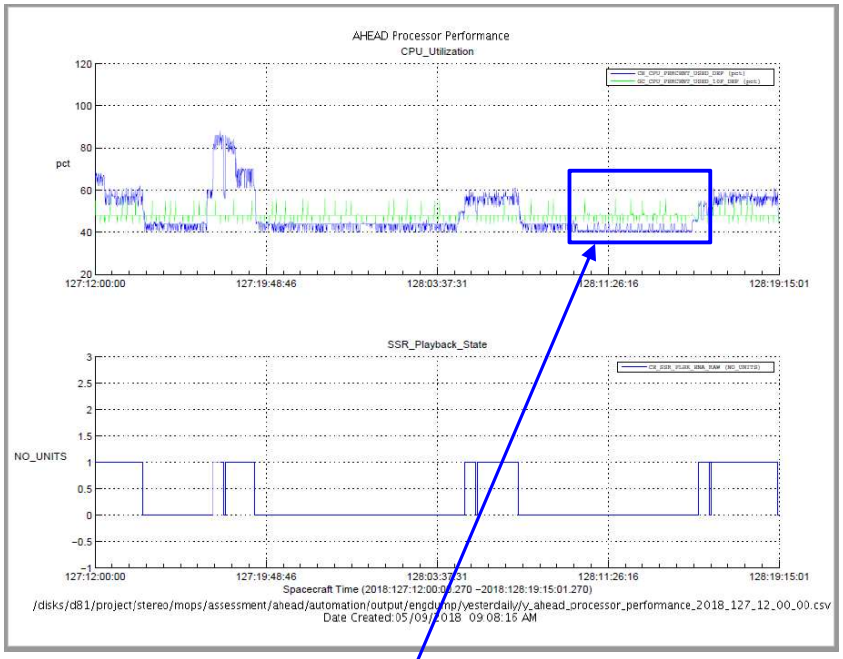
1st Shift Activities

Test Director:	Matthew Cox	*Electrical Tech:*	
Test Conductor:		*Mechanical Tech:*	

Shift 1 Activities	2018-135-1730z BOT with DSS 14
	1744z Started Momentum Dump CMD Load
	1840z Finished Momentum Dump CMD Load
	1840z Started UT CMD Load
	1923z Finished UT CMD Load
	200000 Momentum Dump Ignition
	200317 Momentum Dump Finished
	2008z Sent CMD to Clear AUT TTs

109th Mom-Dump

43rd SECCHI-step-cal: 8-May-2018 (Day-128)
Roll out-of-contact – ~40% CPU
240kbps (34m) contact after roll – ~55% CPU



43rd SECCHI step-cal

* On day 128 (May 8), the 43rd SECCHI stepped calibration was executed at 1030z for aphelion in the Ahead orbit. This was the 12th SECCHI stepped calibration roll to be conducted without gyro use.

FSW Monitoring Activity

With return to "Nominal Ops":

- **FSW receives & reviews daily emails on S/C FSW health**
  - **Summarizes any flight-software anomaly activity**
  - **Examples: recent ST-CPU-reset; SECCHI-reset/recovery; memory-SEUs, etc…**
- **Review of MOPs shift reports and weekly status summaries**
  - **Maintain awareness of mission- and system-level activities.**
- **FSW maintains contact w/ MOPs / Engineering team as needed**
  - **Alerts MOPs personnel to any "odd behavior" observed**
  - **Acts as a "second pair of eyes" on monitoring S/C health**

Backup Info

Backup Item

Excerpt from:

STEREO 2016 Annual Assessment:

Flight-Software

15-June-2016

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Fault-Protection & Autonomy

- **A look back: Fault-Protection / Autonomy Areas addressed / tuned:**
  - Refining ST being primary G&C-sensor
    - 15-Dec-2014: TEC-Set-Point Temperature reduced from +20 to -10-deg-C
  - IMU-remaining-life
    - 27-Jan-2015: Protect against bad-data-flowing into G&C (BEHIND)
      - Patch applied in MOP-Perm-1.1.17
    - Post-Solar-Conjunction 2016 forward: Limit IMU-operation to Fault-Protection only
      - Reduce IMU turn-on / turn-off cycles
      - Reduce IMU running-time
  - Autonomous-Mom-Dumps
    - Distinguish between:
      - Routine Mom-Dumps (via ST; IMU-off)
      - Autonomous Mom-Dumps (IMU-on)
- **Recent (NGO-2.3.19) Enhancements:**
  - Wheel-protection / Wheel-overspeeds
  - DSAD / ST cross-checks
    - Aka: Solar-Array pointing
    - Aka: Solar-Array power (pre-sLVS)
- **Looking to the future:**
  - Antenna Cycling (resumption of Comm following an event @ <2-AU.)
    - Sequencing of HGA and LGAs may evolve…

AHEAD NGO-2.3.18 (20151013)

Content Summary – by Change Request
(Excerpt from 12-Nov-2015 NGO Review)

Primary Release Motivators:

- **CR-6885: R129 :: For Autonomous-Mom-Dumps, turn IMU-on**
- **CR-6880: R130/M149 :: Abort any Mom-Dump if both ST and IMU are invalid**
- **CR-6881: R019 :: Increase RGO's Loss-of-IAK→ST-reset rule persistence (0.5 → 2 min)**
- **CR-6852: R127 :: Increase RGO's ST-fault/IMU-on rule persistence (1→30 min)**

Raise to level of fix while the hood-is-up:

- **CR-6859: M034 :: Remove redundant IMU usage enable cmd from sCLT response**
- **CR-6823: M068 (response to ST fault during contact) :: Remove ST suspend cmd**
- **CR-6861: R029 :: (Disable Loss-of-IAK #2; R028 offers preferred protection)**
- **CR-6877: no real change; (sLVS loadfile book-keeping only)**
- **CR-6889: M071 :: Don't disable MOPs time-tags/rules/macros should Rule-98 fire upon an aborted Mom-Dump. (F.P. since launch DID disable.)**

Additional NGO-2.3.18 (20151013) fixes while hood is up
(Excerpt from 12-Nov-2015 NGO Review)

- **CR-6858 - Separate IMU on/off Macros between MOps and Fault-Protection**
- **CR-6900 - G&C-Params/G&C-control-loop-gains VALUES for IMU on**
- **CR-6904 - Disable Wheel Speed Avoidance when Rolling**
  - **Affects M011 and M034 (sLVS and sCLT)**
- **CR-6905 - Turn-on IMU for sCLT-rotations.**

CR-6890 (Content-of-NGO-2.3.18) was updated and brought to CCB for approval.

Post-Conjunction NGO-AHEAD-2.3.19 CRs
(14-Apr-2016)

Primary Motivators:

- **CR-6907 – Wheel Overspeed Protection (Reset Wheel)**
  - **Autonomy-Lead Comment: An 'elegant' solution exists!**
- **CR-6895 – Compare X-axis to Sun-axis**
  - **Ensure S/C is Sun-Pointing (and power-positive!).**

Or simply: anticipating next likely faults (*as informed by Solar-Conjunction*):
a. wheel-overspeed or failure(s); *(we also have 1-wheel redundancy)*
b. Primary G&C-sensor, the-ST, is 'lying' to us, (or G&C is confused)…

Other ~~Possible~~ Candidates:

- **CR-6910 – EEPROM-Write Timing of SV (and CTs)**
  - **SV02 upload to EEPROM – issue seen 14-Dec-2015 (shift-report #2272)**
- **CR-6914 - NGO-AHEAD-2-3-19: Consider changing R127's hair-trigger persistence**
  - **From: 1800-of-1800-seconds To: 1800-of-1920**

Backup Item

Excerpt from:

STEREO 2013 Annual Assessment:

Flight-Software

13-March-2013

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From 2013 Annual Assessment:
Other Post-launch FSW Applications Available

- **C&DH 3.2.4**
  - Released 14-May-2007
  - Addresses:
    - Permanent fixes to 3 issues currently addressed as RAM patches to in-flight C&DH 3.2.3
    - Phantom 1553 message failure issue
- **G&C 3.2.3**
  - Released 14-May-2007
  - Addresses:
    - Permanent fixes to issues addressed as RAM patches to G&C 3.2.2
    - G&C algorithm enhancements to HGA and Guide Telescope
- **G&C 3.2.4**
  - Released 9-Jan-2008
  - Addresses G&C algorithm enhancements to merge rates from IMU and ST
- **G&C 3.2.5**
  - Same as G&C 3.2.4, but built with Matlab R2008a (7.6) (not released)
- **G&C releases above superseded by G&C 3.2.6 now flying.**

From 2013 Annual Assessment:
C&DH Patches

Current C&DH 3.2.3 Patches			
Patch	**Description**	**Delivered to MOps**	**Patch Release**
patch-1	DST-config-table patch	6/1/2006, Updated 2/19/2007	3.2.3, p1
patch-2	ECC single-bit-error handler patch	11/1/2006, Updated 2/19/2007	3.2.3, p2
patch-3	Relax health monitoring patch	2/19/2007	3.2.3, p3

From 2013 Annual Assessment:
CRs fixed in C&DH 3.2.4

CRs fixed in C&DH 3.2.4				
CR-ID	**PFR-ID**	**AR-ID**	**Description**	**Equiv RAM Patch Release**
5034			M: CDH/EA: Data Summary Table (DST) data inconsistent (permanent fix)	3.2.3, p1
5435	1 (old 257)	MOPS 22/24	M: CDH/EA/GC: Coding error in common ECC memory error handler (perm fix) - CDH	3.2.3, p2
5458		MOPS 51	M: CDH/EA: Relax CDH-cpu Health Monitoring (perm fix)-CDH	3.2.3, p3
5412	3 (old 259)	MOPS 39	M:CDH/EA-BC-1553 RETRY_MSG message causes repeating phantom transaction failure counts - CDH	<na>

Why the EA Bypass Switch was Set (Excerpt from 12-Feb-2015 Sol-Conj Readiness Review)

- **Earth Acquisition Mode software uses IMUs and Sun Sensors as the primary attitude sensors**
  - **IMUs are now a limited-life item**
- **Earth Acquisition Mode software uses LGAs only**
  - **The Earth will be at the edge of the LGA antenna patterns during conjunction**
  - **LGA usage at distances near 2 AU is not robust, especially with 34m DSN antennas**
  - **LGA usage requires lowest data rates, which increases susceptibility to solar scintillation interference**
- **For the next year, the HGA provides best chance to reestablish contact after conjunction or after a critical fault**
- **Standby Mode still cycles through all 3 antennas within 72.3 hrs if contact with ground not established**
- **Instrument science is not possible in EA mode**
- **EA autonomy rules are not compatible with Reduced Gyro Operations (RGO)**

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Thermal Subsystem Assessment

- **Scope of Review**
  - **Assessment Period: 5/1/2016 – 7/10/2018**
  - **Only the AHEAD Spacecraft is being Reviewed**
  - **Spacecraft and Subsystem Component Temperature Histories**
    - **Temperature Histories are Provided in Charts Thermal-8 to Thermal-29**
  - **Spacecraft Heater Operation (Review Average Duty Cycles)**
  - **Instrument Interface Temperatures**
    - **Interface Temperature Plots are Provided in Charts Thermal-28**
  - **General Status Items**
    - **Heater Duty Cycle Values**
    - **Temperatures**
    - **Solar Flux Variation During Status Period**
    - **Silver Teflon Solar Absorptivity (α) Degradation**

Thermal Subsystem Assessment

- **Status**
  - **Heater Duty Cycle Values**
    - **Heater Duty Cycle Info Provided in Charts Thermal-8,23,27**
    - **Plots Indicate Plenty of Heater Margin**
  - **All Temperatures are Within Operating Limits**
  - **Solar Flux Variation During Assessment Period (Based on Min to Max Solar Range Variation)**
    - **2.4% Increase for AHEAD Max to Min Sun Range Variation (Chart Thermal-7)**
    - **ΔT Increase ~ 0.58% for External Surfaces (Less Variation for Internal Surfaces)**
    - **Solar Panel Charts Thermal-10 Provides a Good Indication of the ΔT Caused by Flux Variation on AHEAD (~2.6°C Increase Over Max to Min Sun Range)**

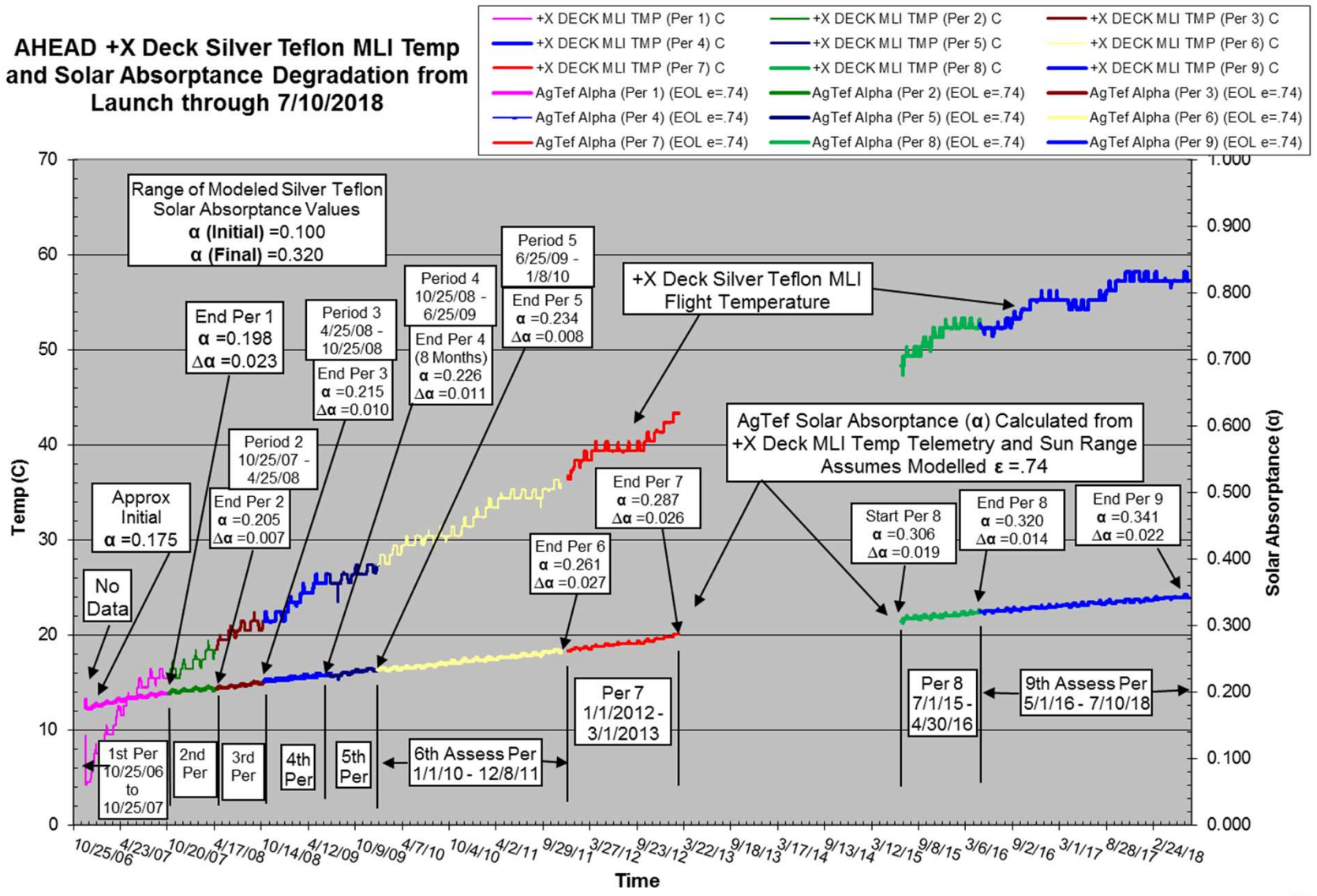
Thermal Subsystem Assessment

- **Status (Continued)**
  - **+X Deck Sun-Facing Silver Teflon Solar Absorptivity (α) Degradation**
    - **Temperature Sensor Placed on Outside of Silver Teflon Layer on Sun-Facing +X Deck Thermal Blanket Allows Calculation of Solar Absorptivity (α)**
    - **Initial α Calculation After Launch: 0.175 (AHEAD), 0.198 (BEHIND) – for Reference**
    - **During Current 26 Month Assessment Period (5/1/2016 to 7/10/2018): Δα~.021**
    - **Latest α Calculation: 0.341 (AHEAD), was 0.320 at End of Previous Assessment Per**
    - **Analysis Cases Assumed Initial α = 0.100, Final α = 0.320 (per the Goddard Coatings Committee), But the Estimate was for 5 Years, STEREO is ~12 Years Old Now**
    - **See Slide Thermal-24 (AHEAD +X Deck MLI) for Details of Degradation During Assessment Period.**
    - **See Slide Thermal-6 for Plot of AHEAD Silver Teflon Solar Absorptivity from Launch Through the Latest Assessment Period.**
    - **Comments/Conclusions**
      - **α on AHEAD is Still Increasing, But the Rate is Decreasing**

Thermal Subsystem Assessment

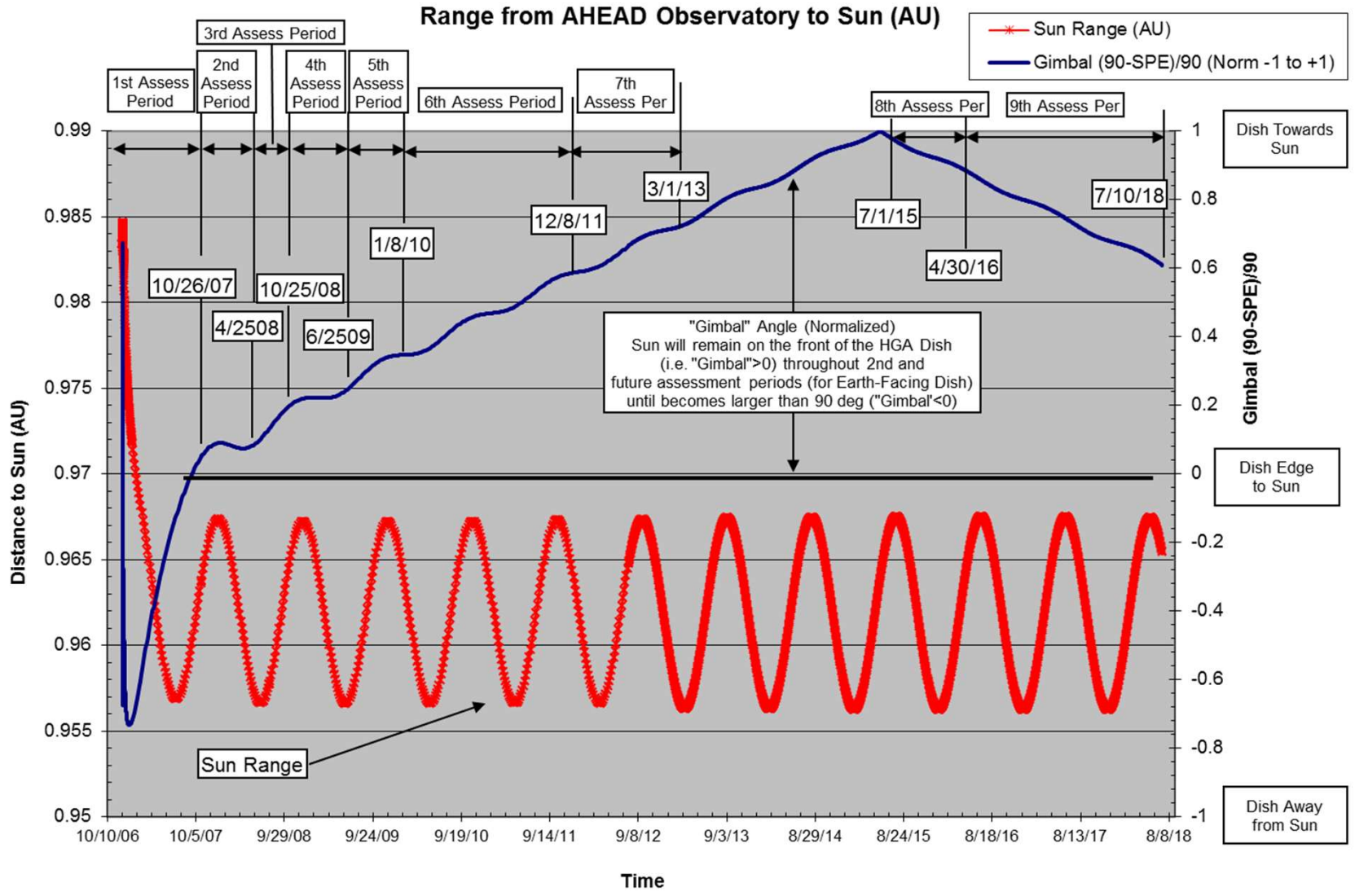
- **Items to Note for Reference to Previous Assessment Reviews**
  - **Operation with Both IMUs Off has Contributed to Some Minor Thermal Changes**
    - **Transponder I/F Temperature Decreased ~ 4°C (on -Y Panel Near –Z, -X and IMU2)**
    - **IMU2 I/F Temperature Decreased from ~25°C to ~5°C (on –X Near –Z Panel)**
    - **Additional Operational Heater Circuit Usage: -Y, -Z, -Z/+Y Service R4**
      - **Low Duty Cycle (0.088)**
    - **SEB I/F Temperature Decreased from ~17°C to ~7°C (on –X Deck, Near IMU2 Location)**

Thermal Subsystem Assessment



Space APL

Thermal Subsystem Assessment



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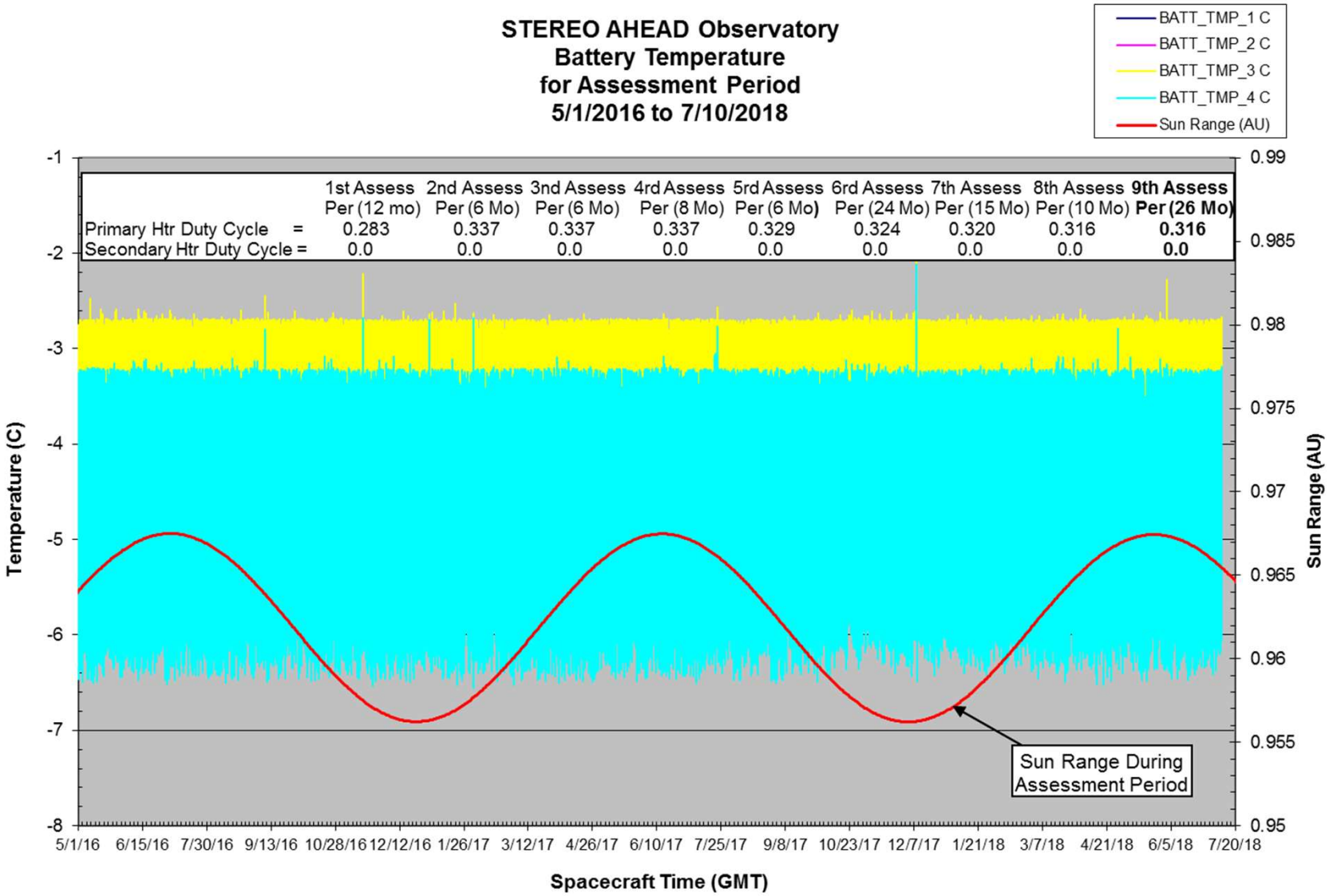
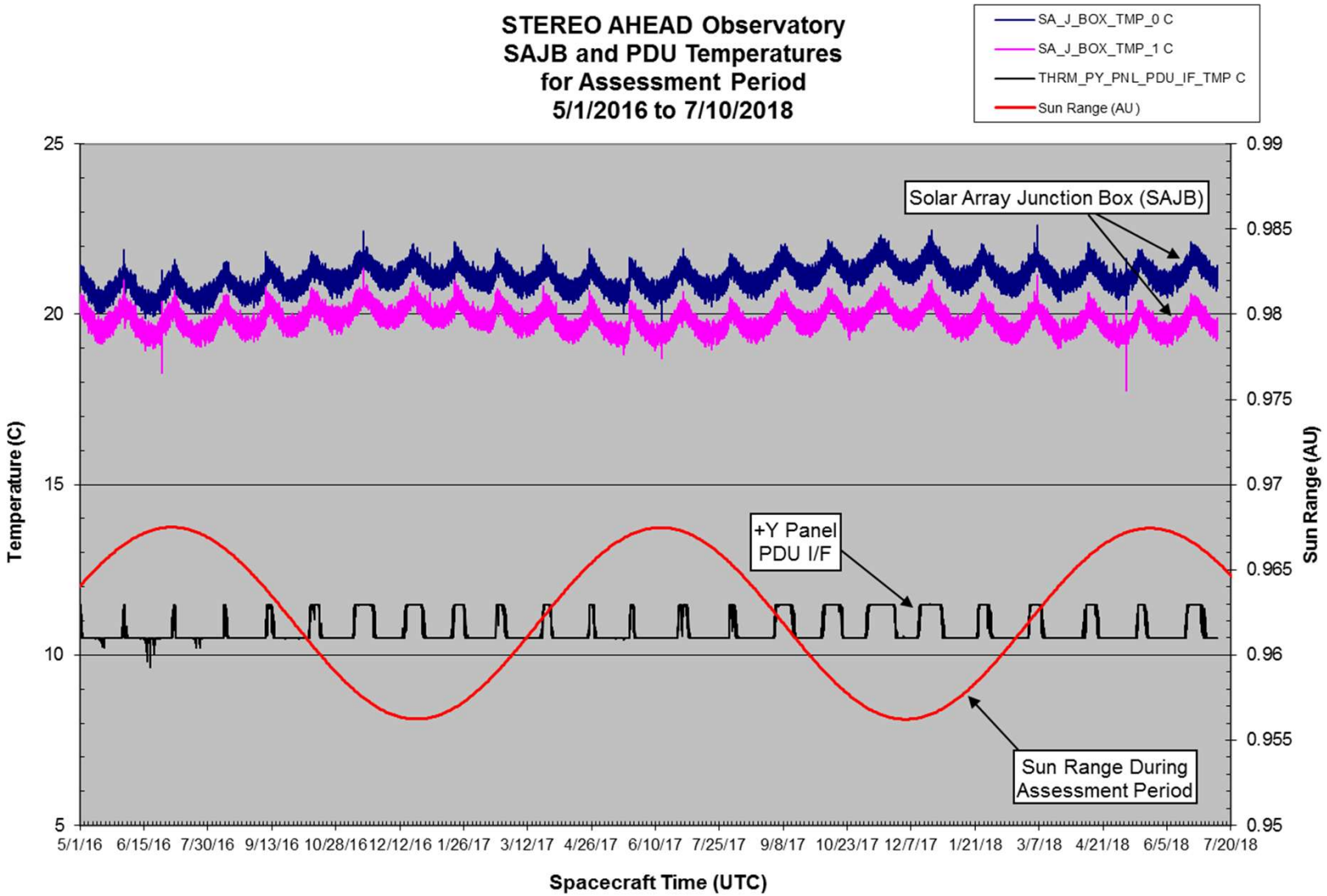
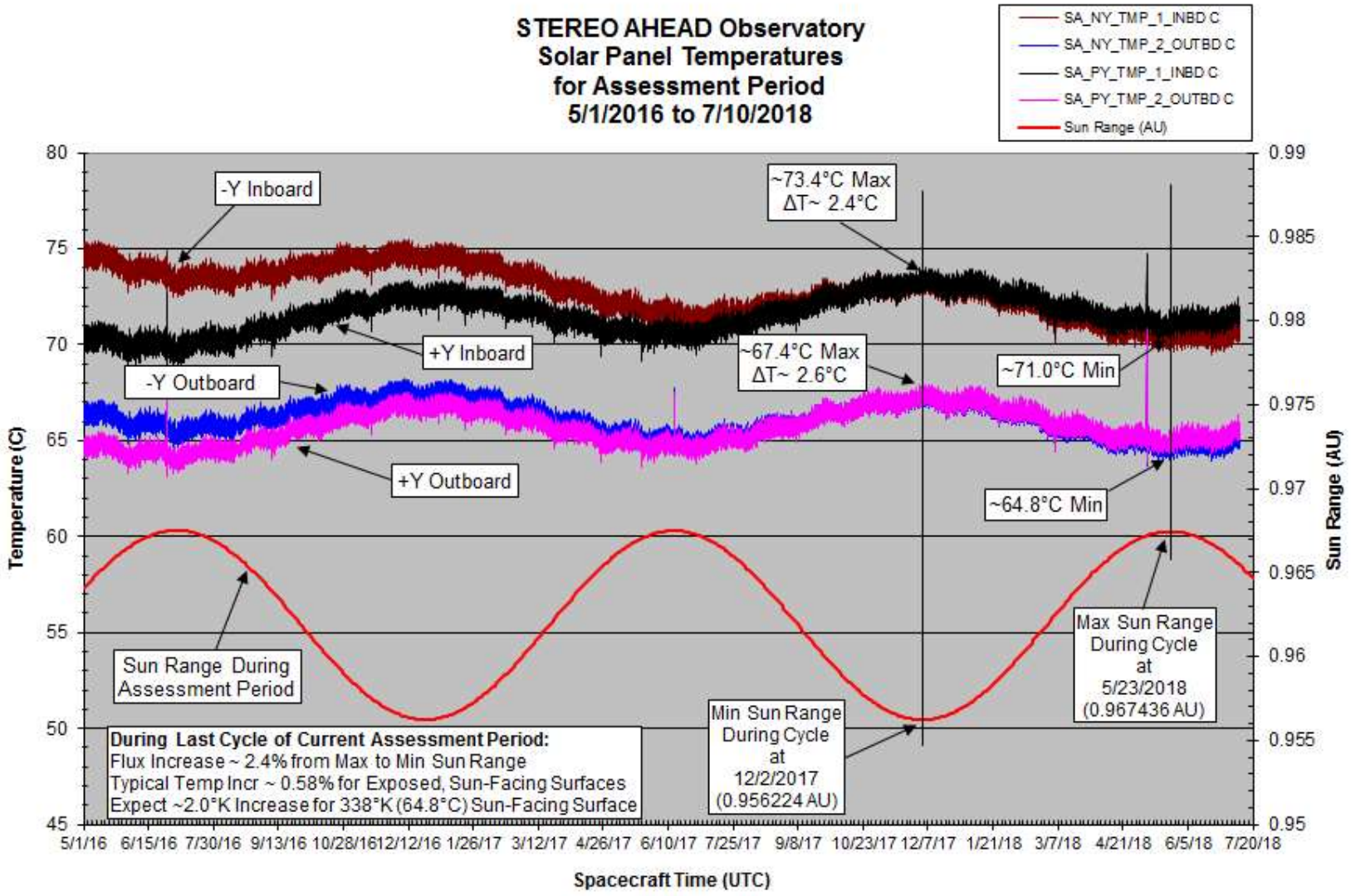
Thermal Subsystem Assessment



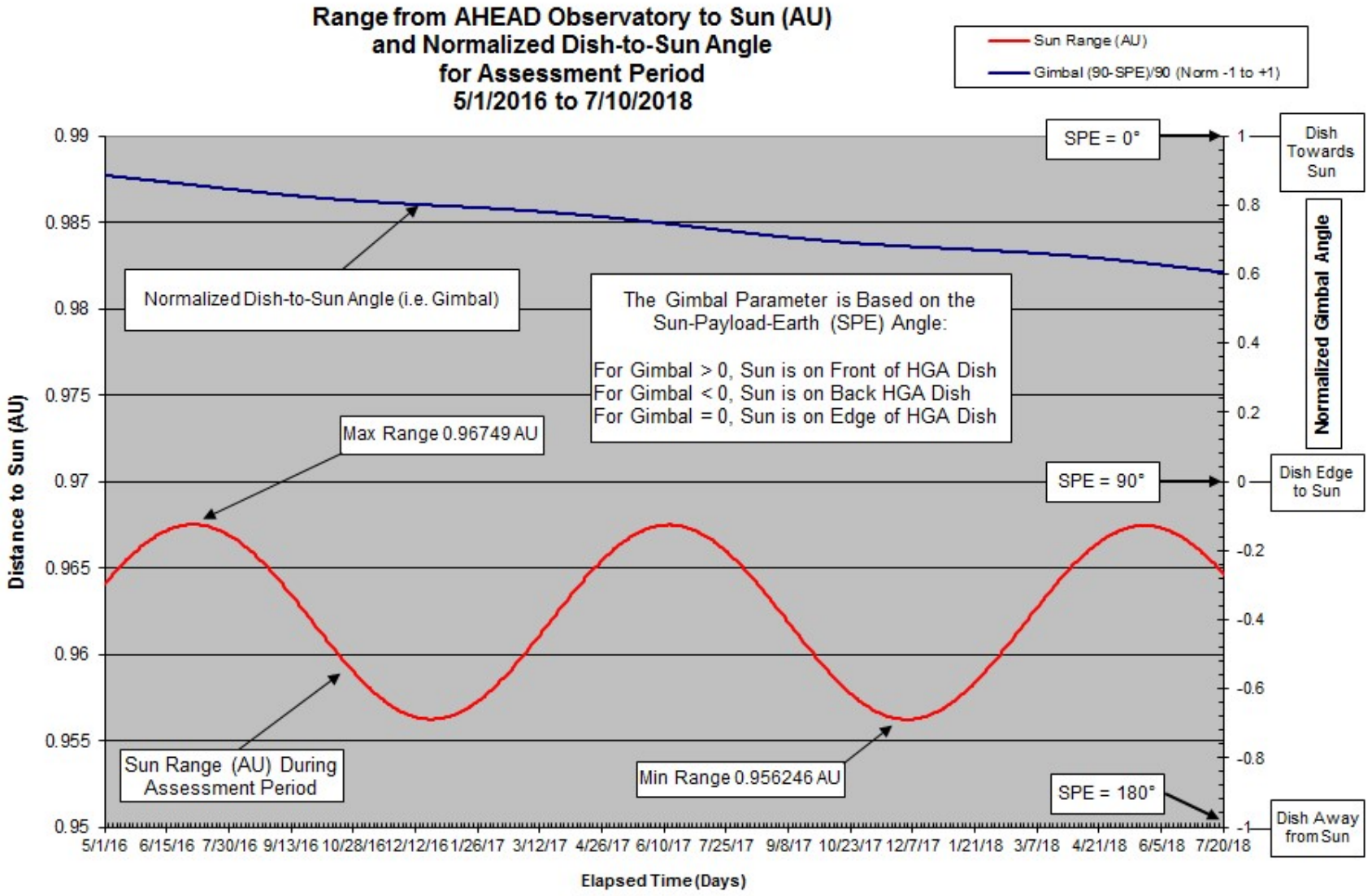
Thermal Subsystem Assessment



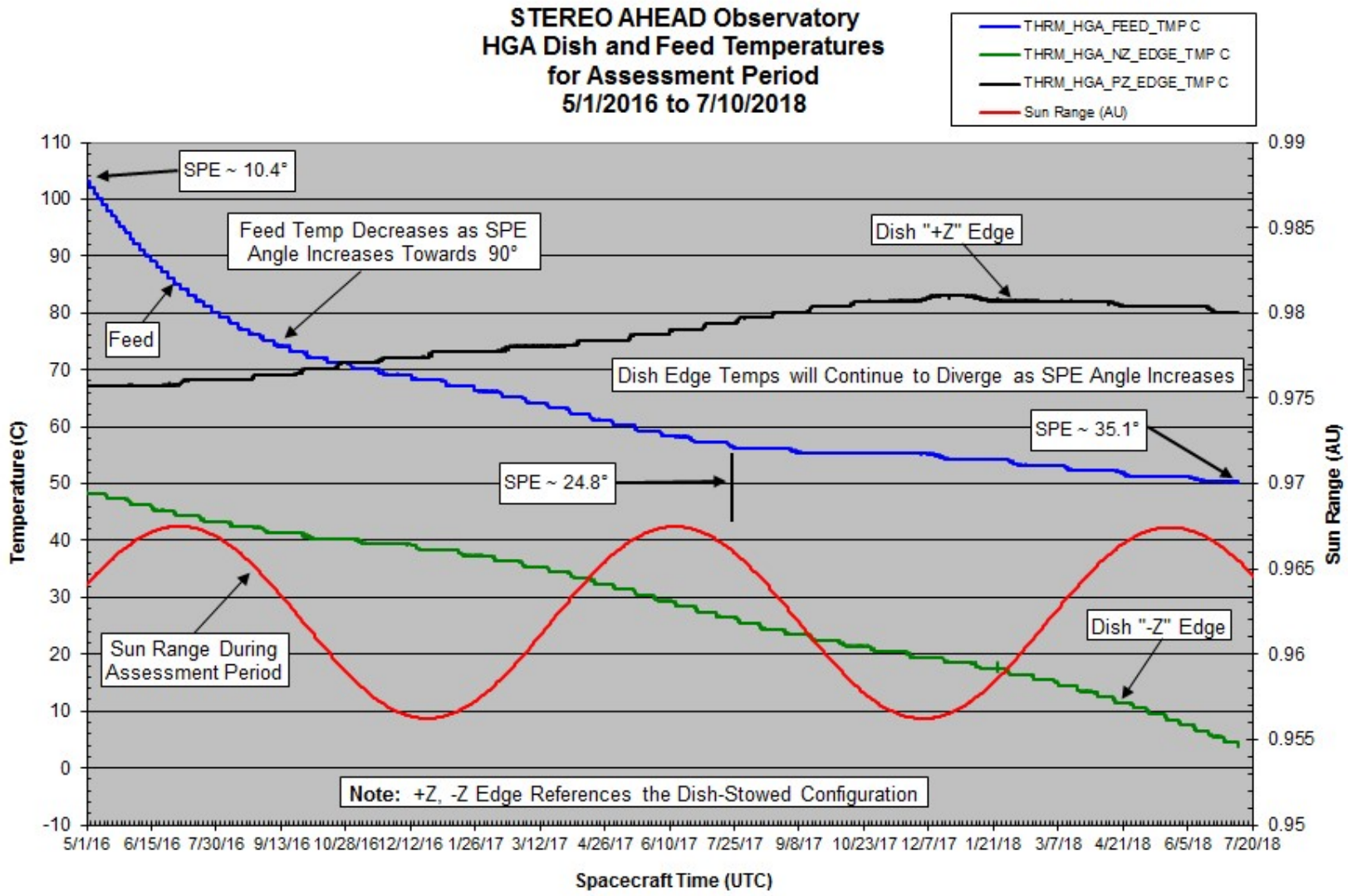
Thermal Subsystem Assessment



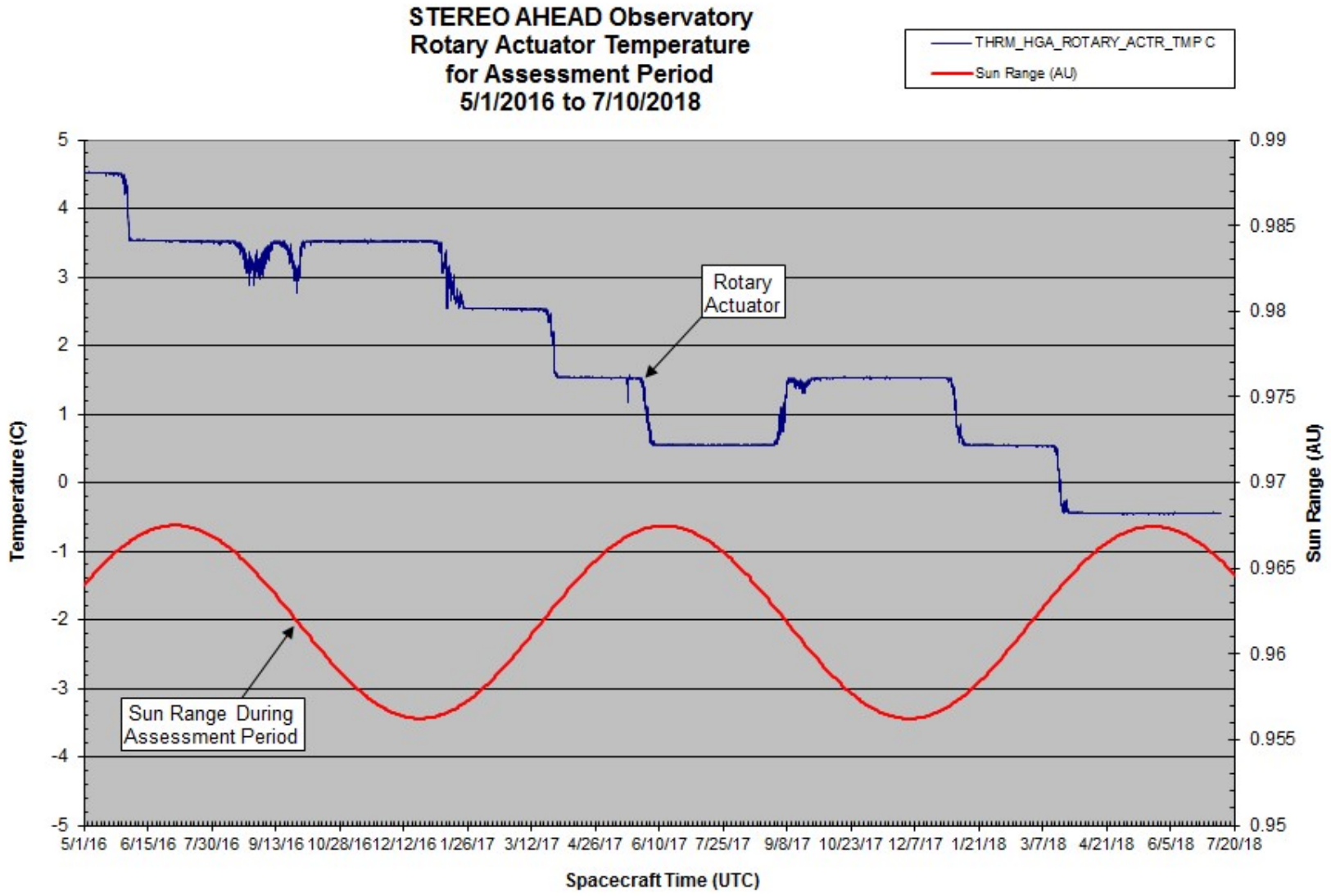
Thermal Subsystem Assessment



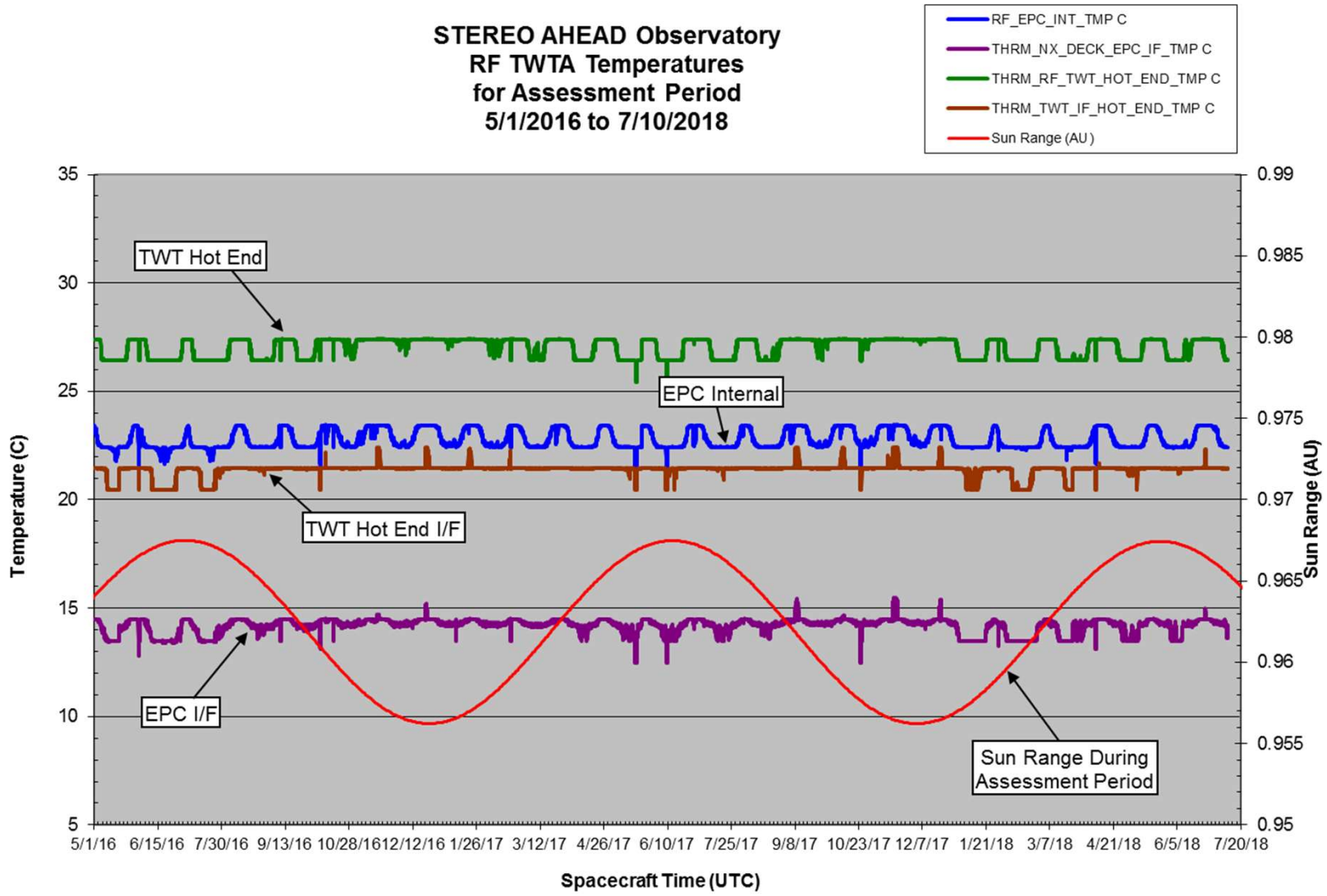
Thermal Subsystem Assessment



Thermal Subsystem Assessment



Thermal Subsystem Assessment



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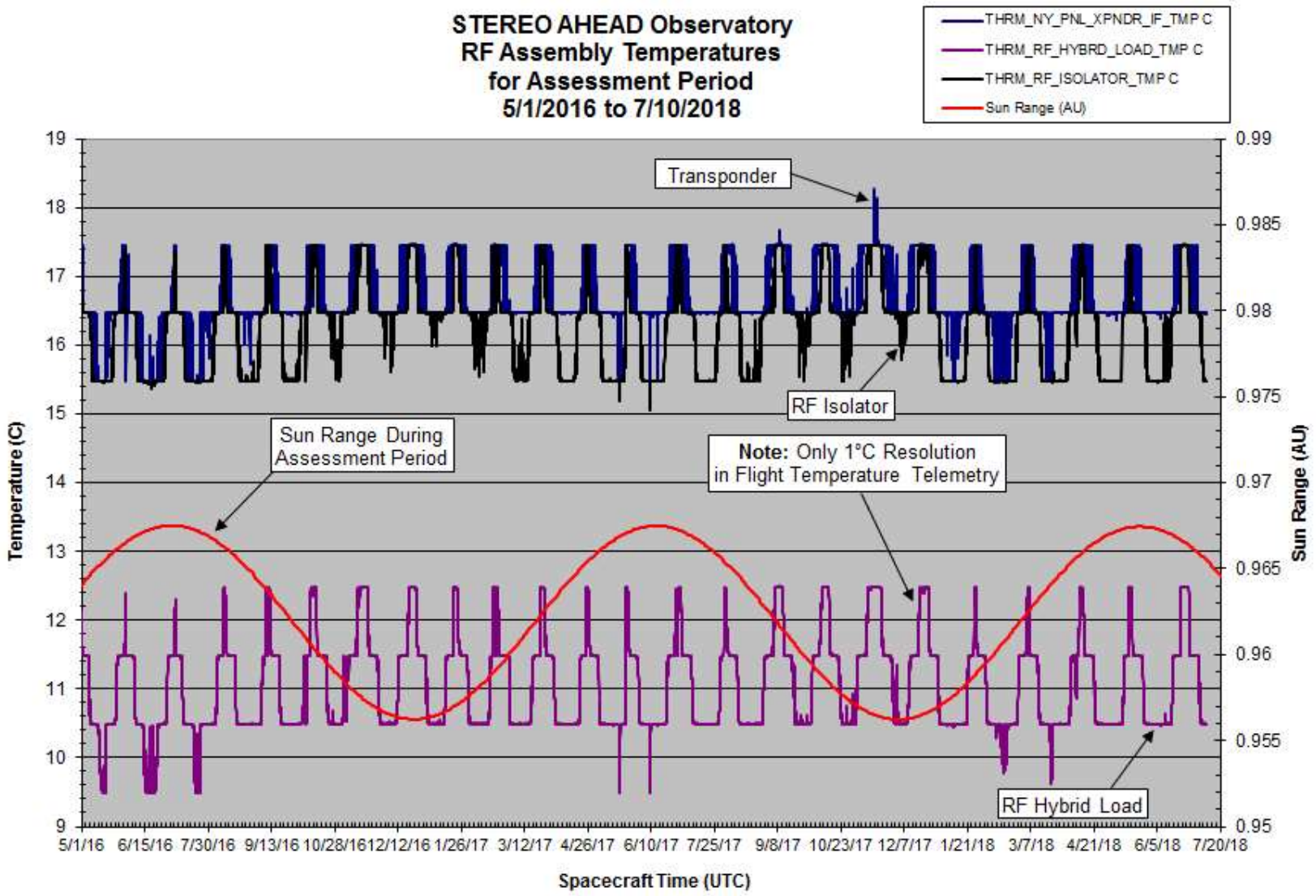
Thermal Subsystem Assessment



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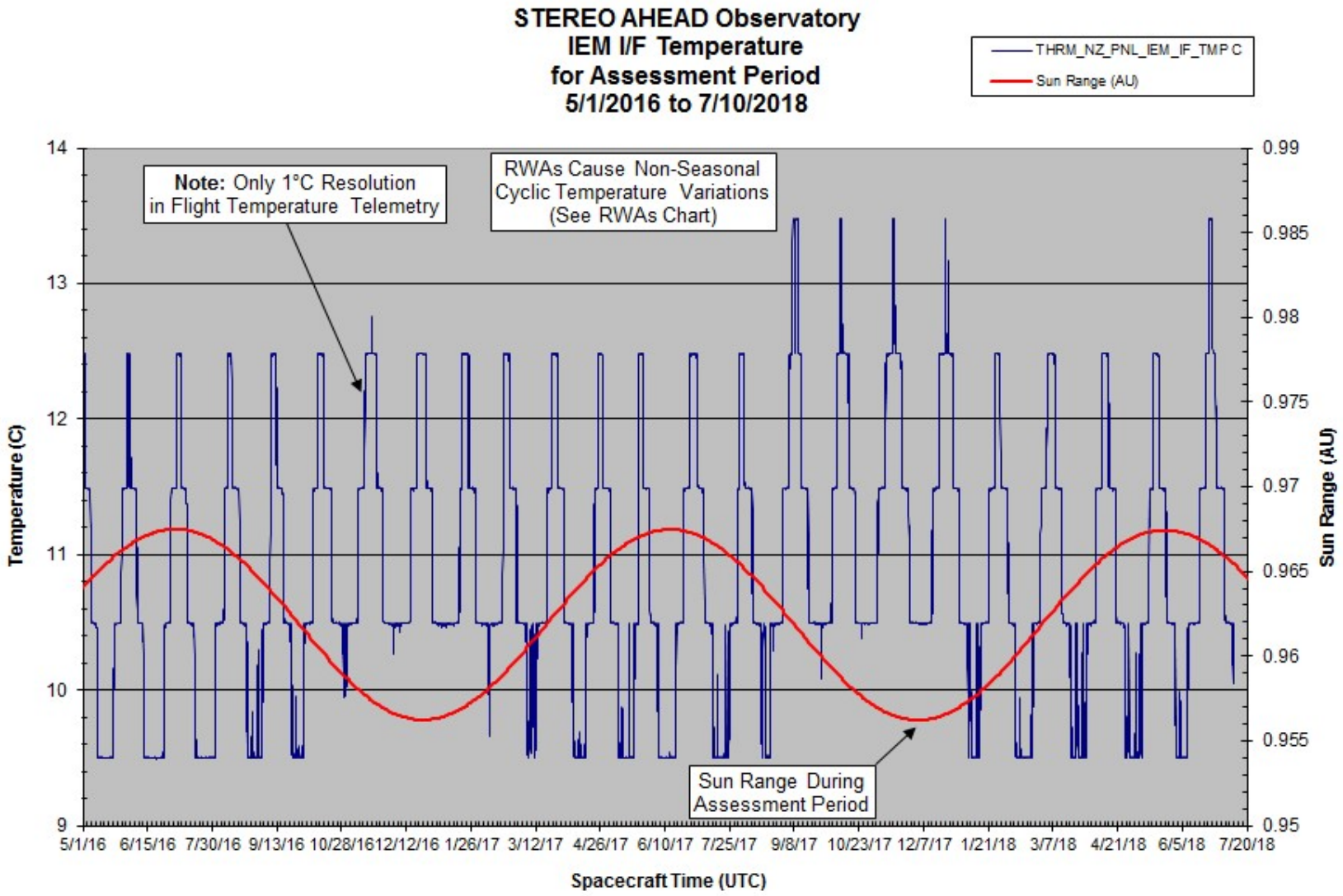
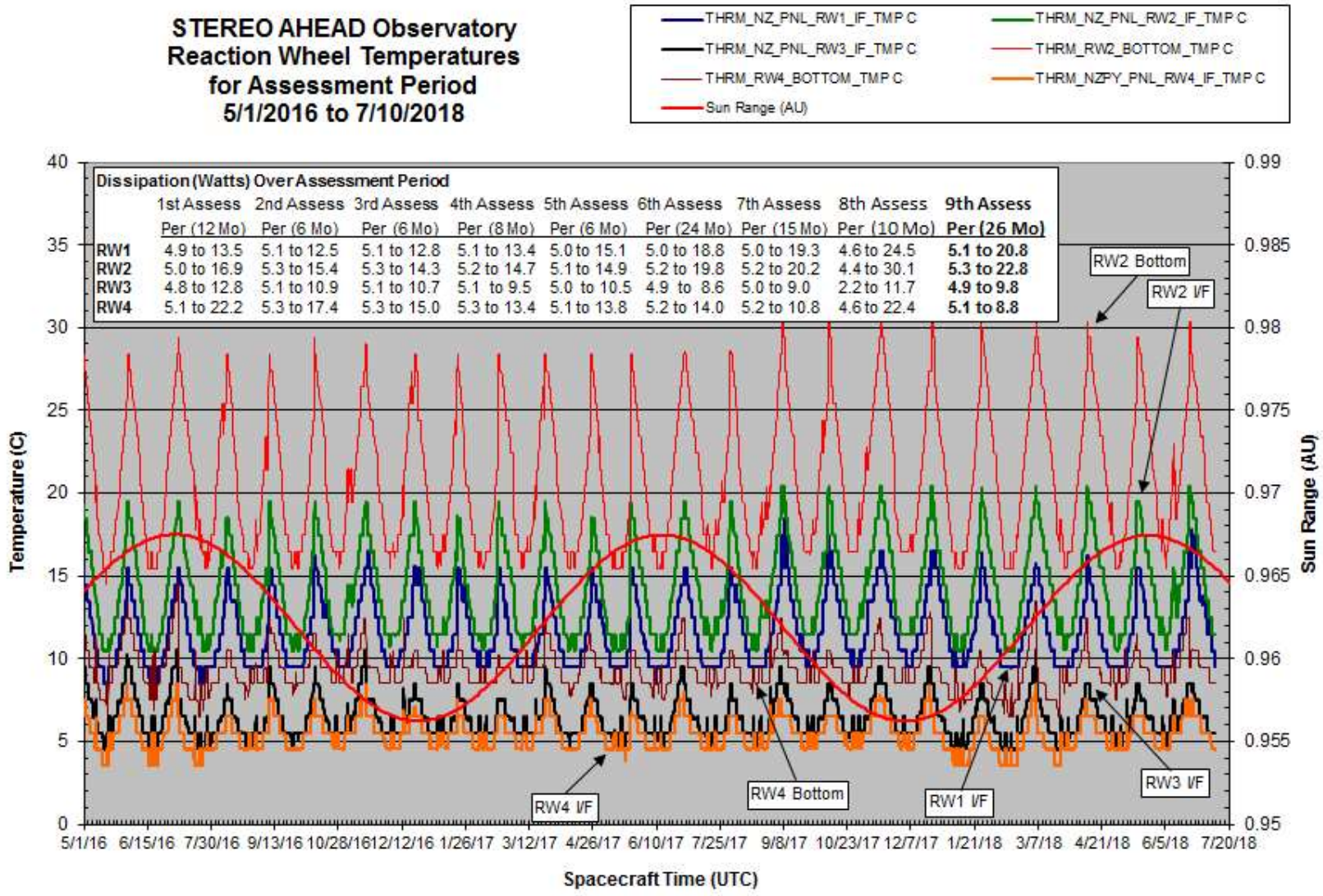


Thermal Subsystem Assessment

STEREO AHEAD Observatory
Reaction Wheel Temperatures
for Assessment Period
5/1/2016 to 7/10/2018



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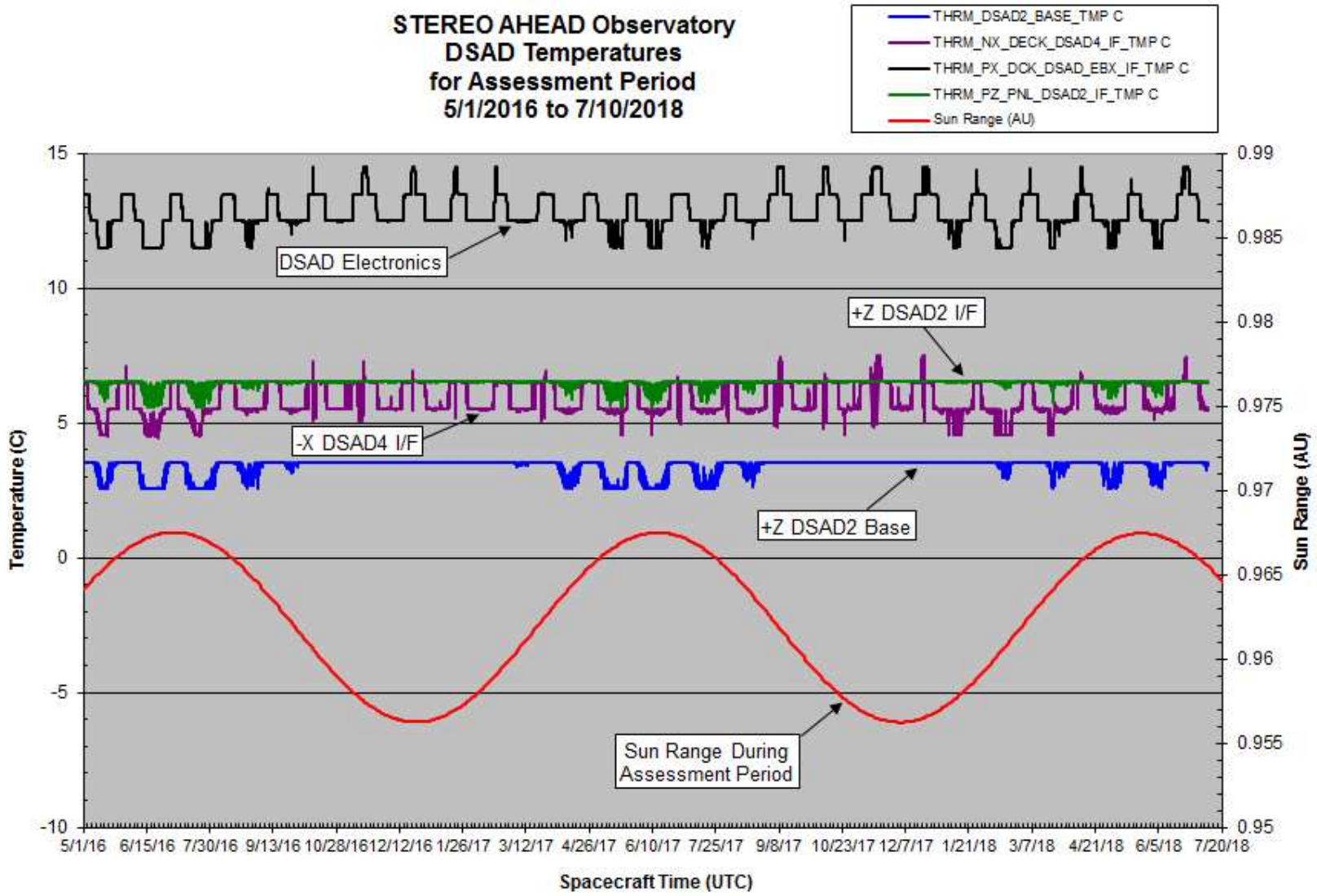
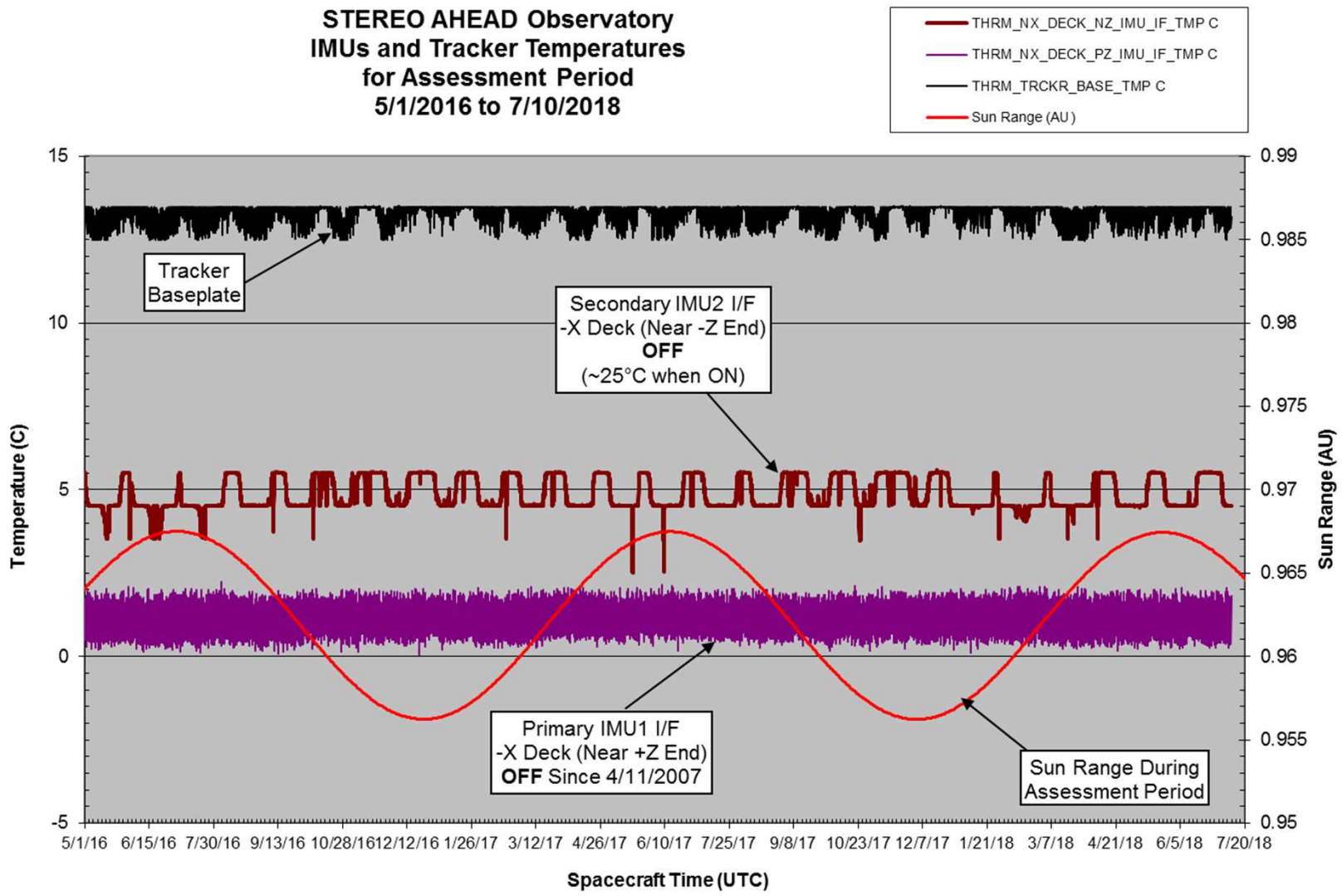


Thermal Subsystem Assessment



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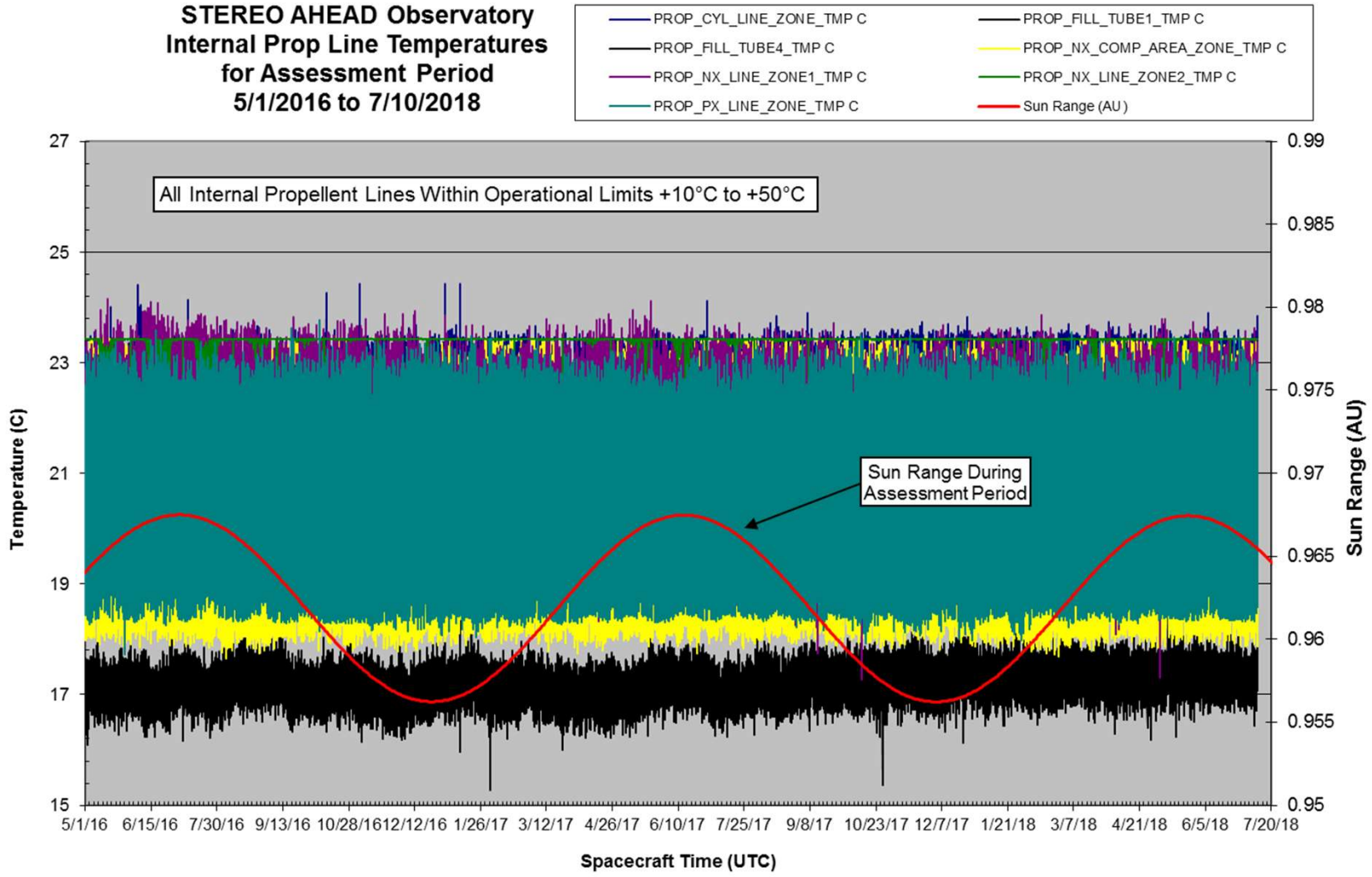
Thermal Subsystem Assessment



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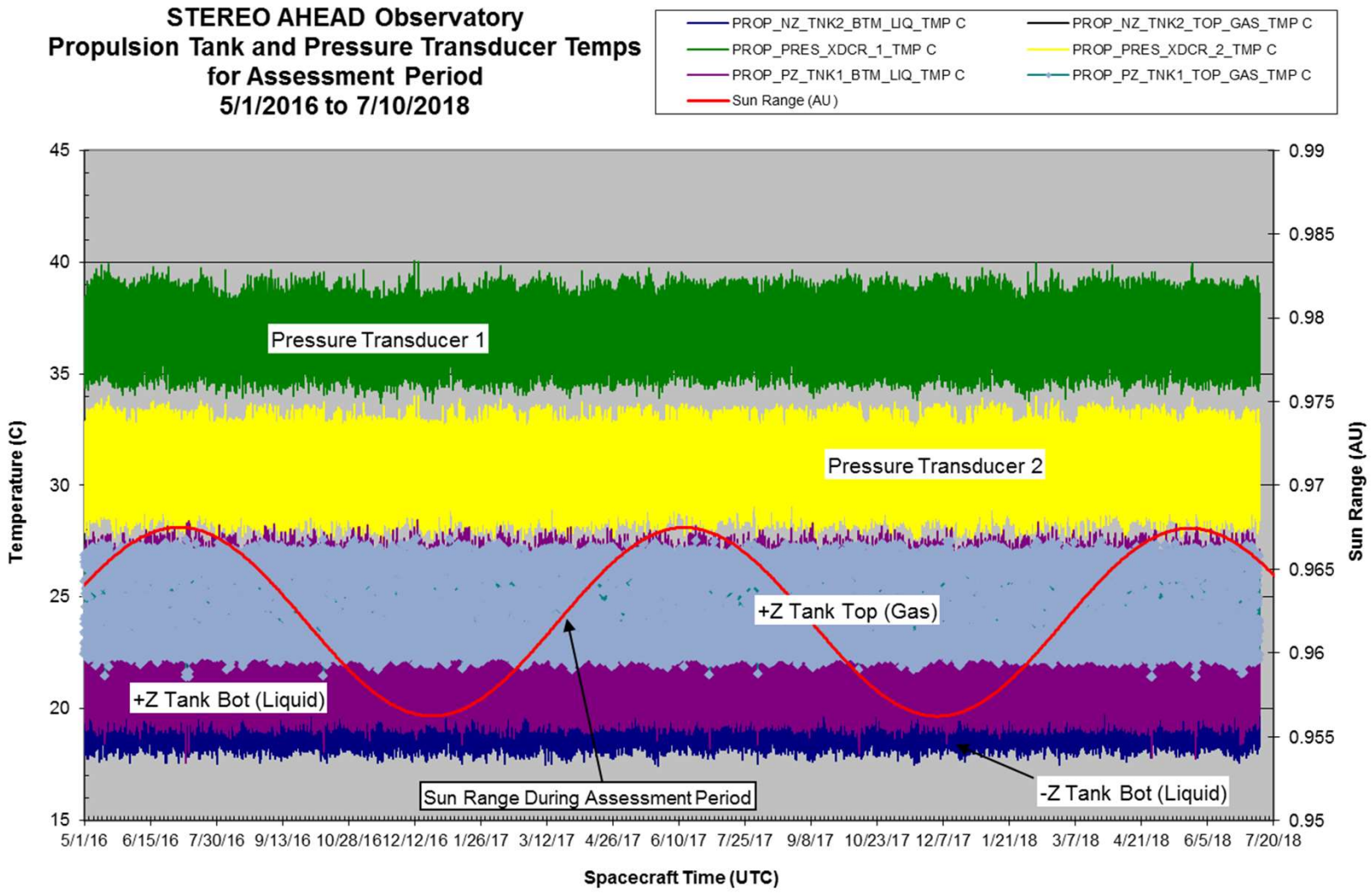
Thermal Subsystem Assessment



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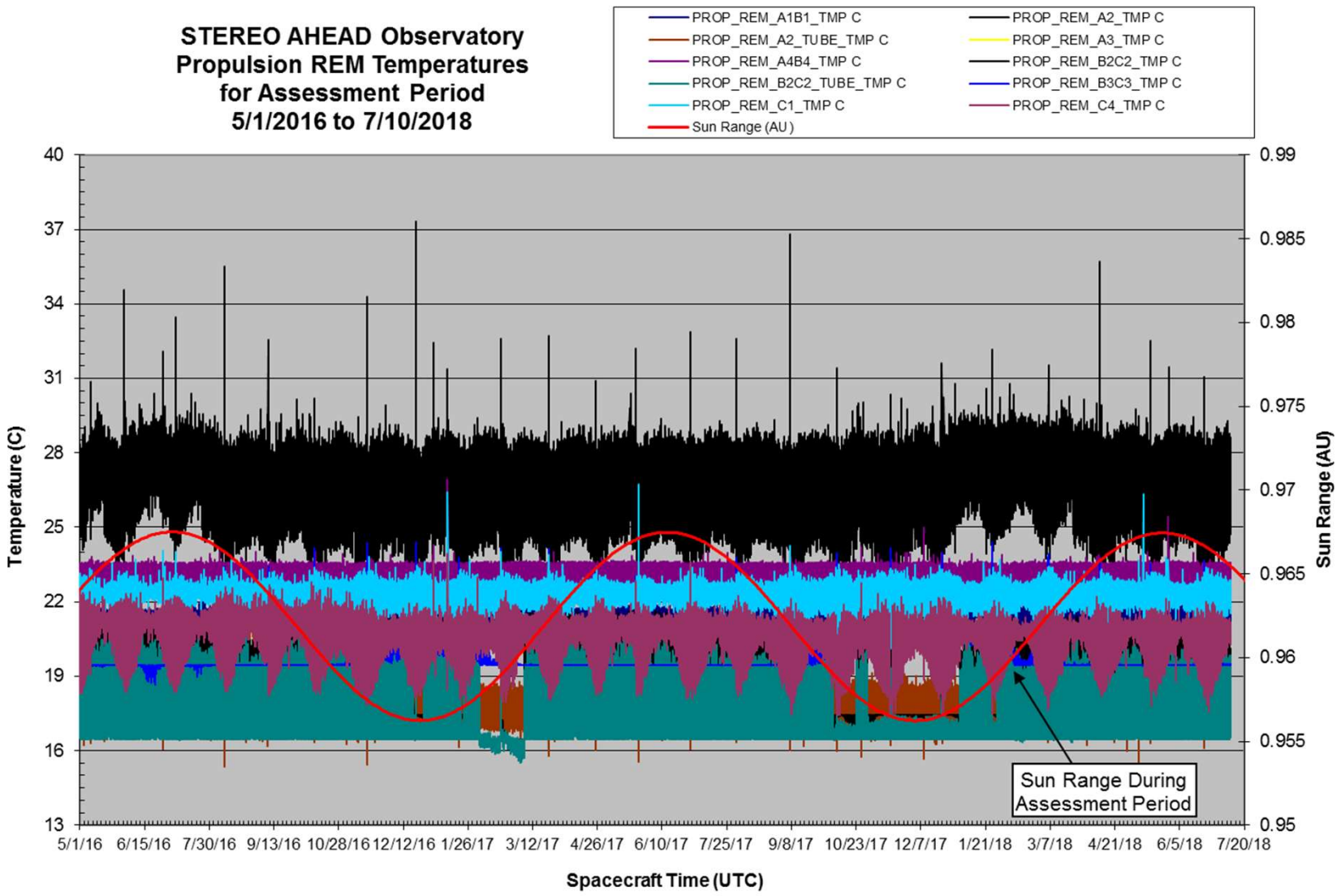
Thermal Subsystem Assessment



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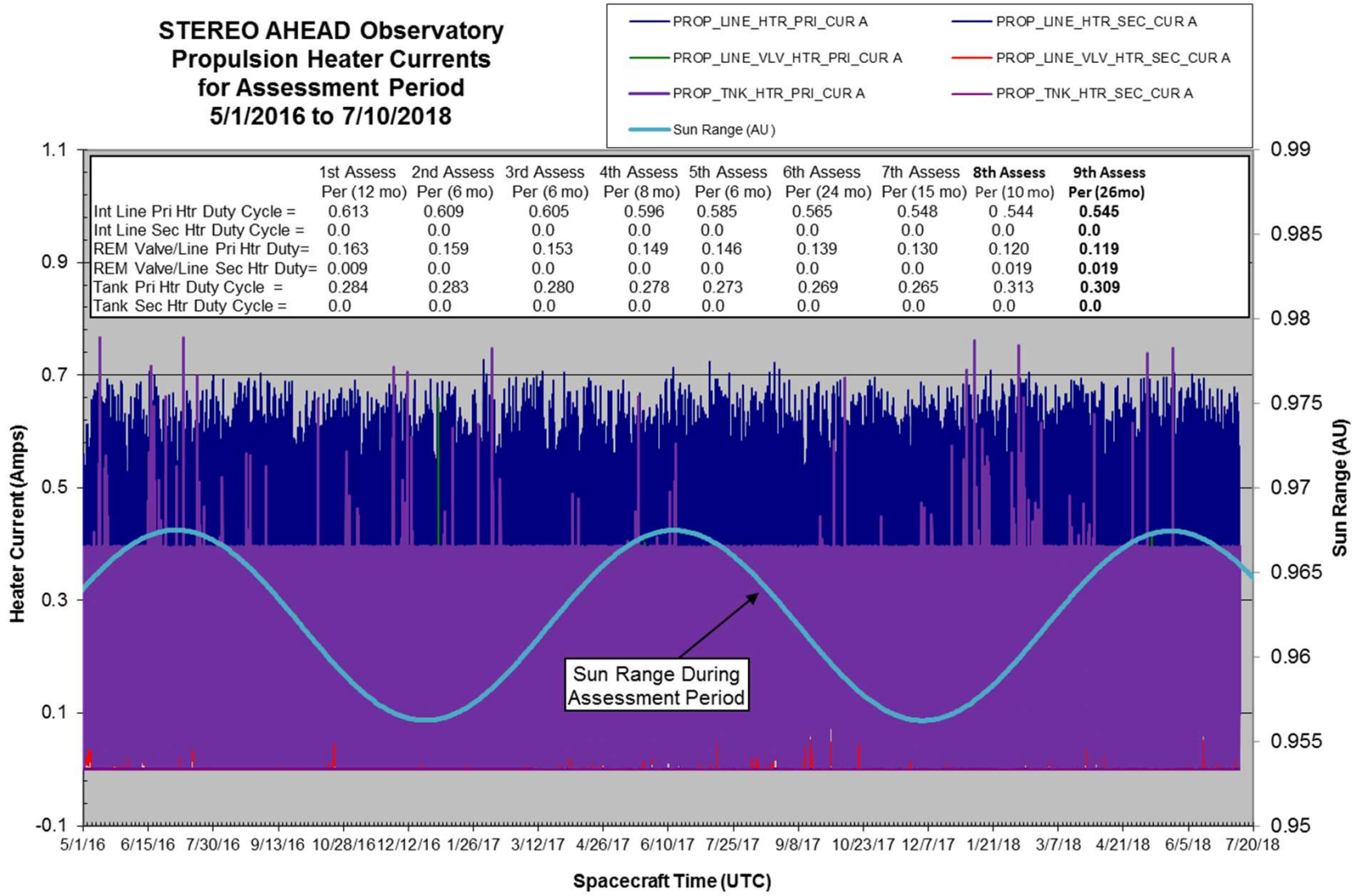
Thermal Subsystem Assessment



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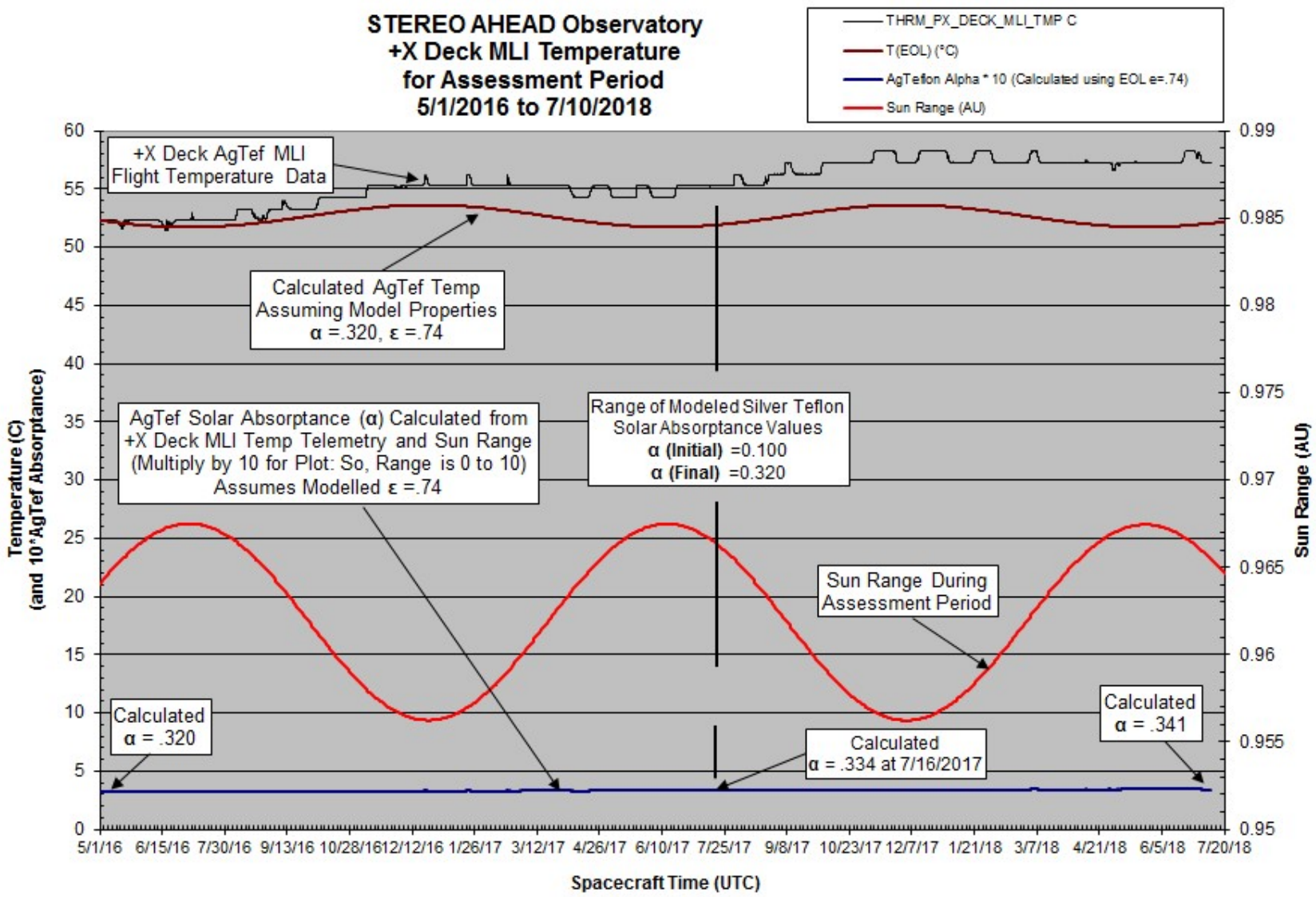
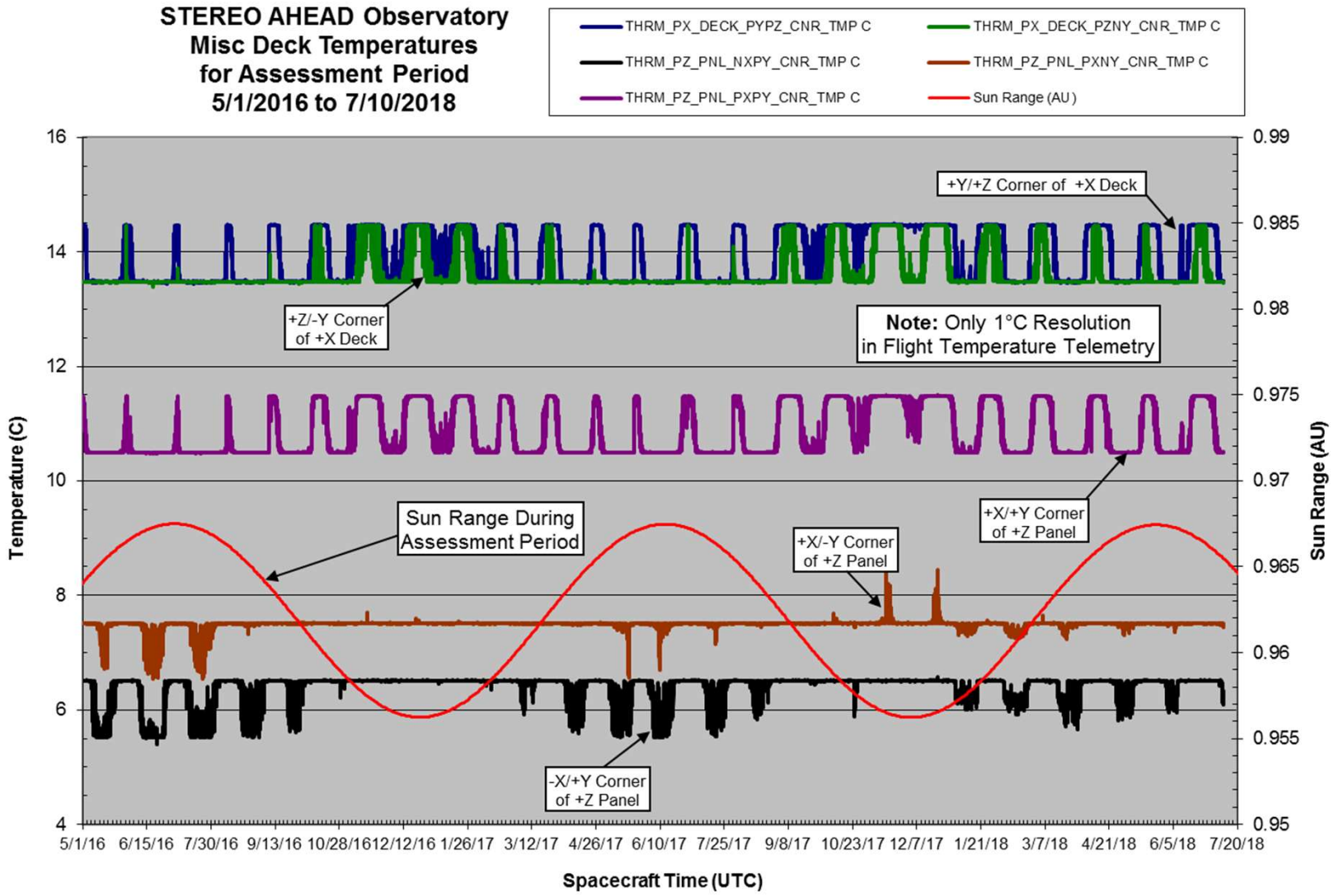
Thermal Subsystem Assessment



Thermal Subsystem Assessment



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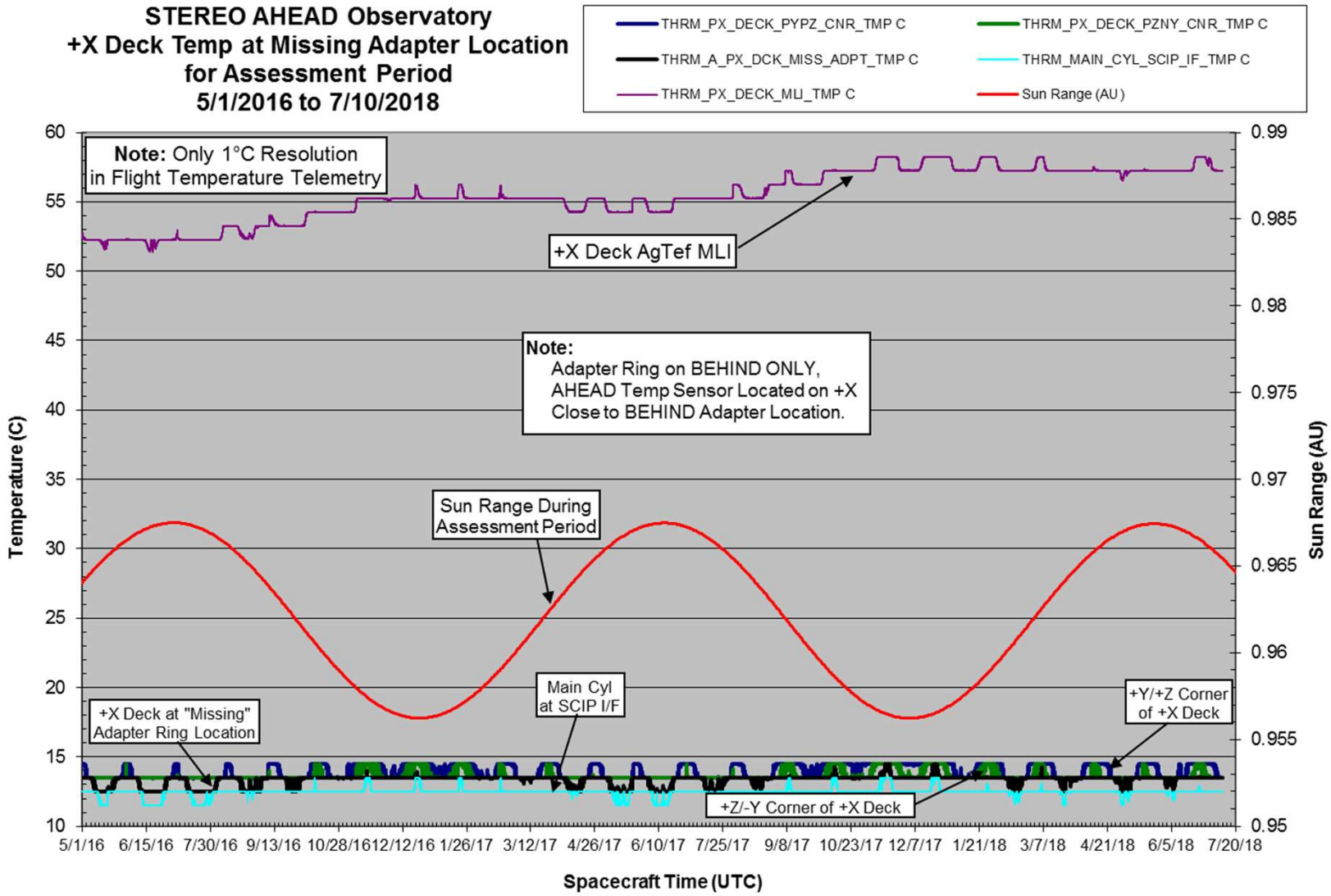
Thermal Subsystem Assessment



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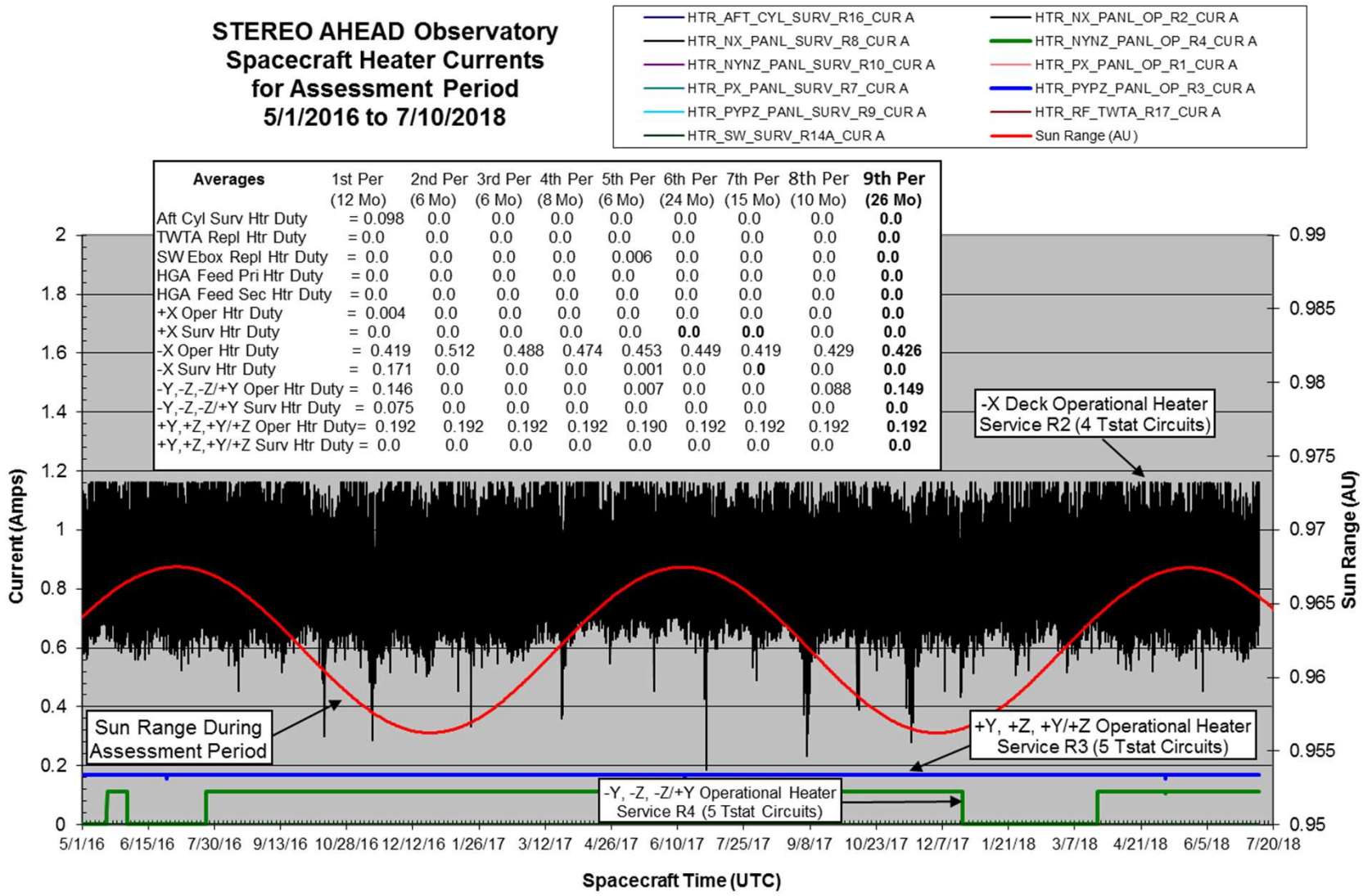
Thermal Subsystem Assessment



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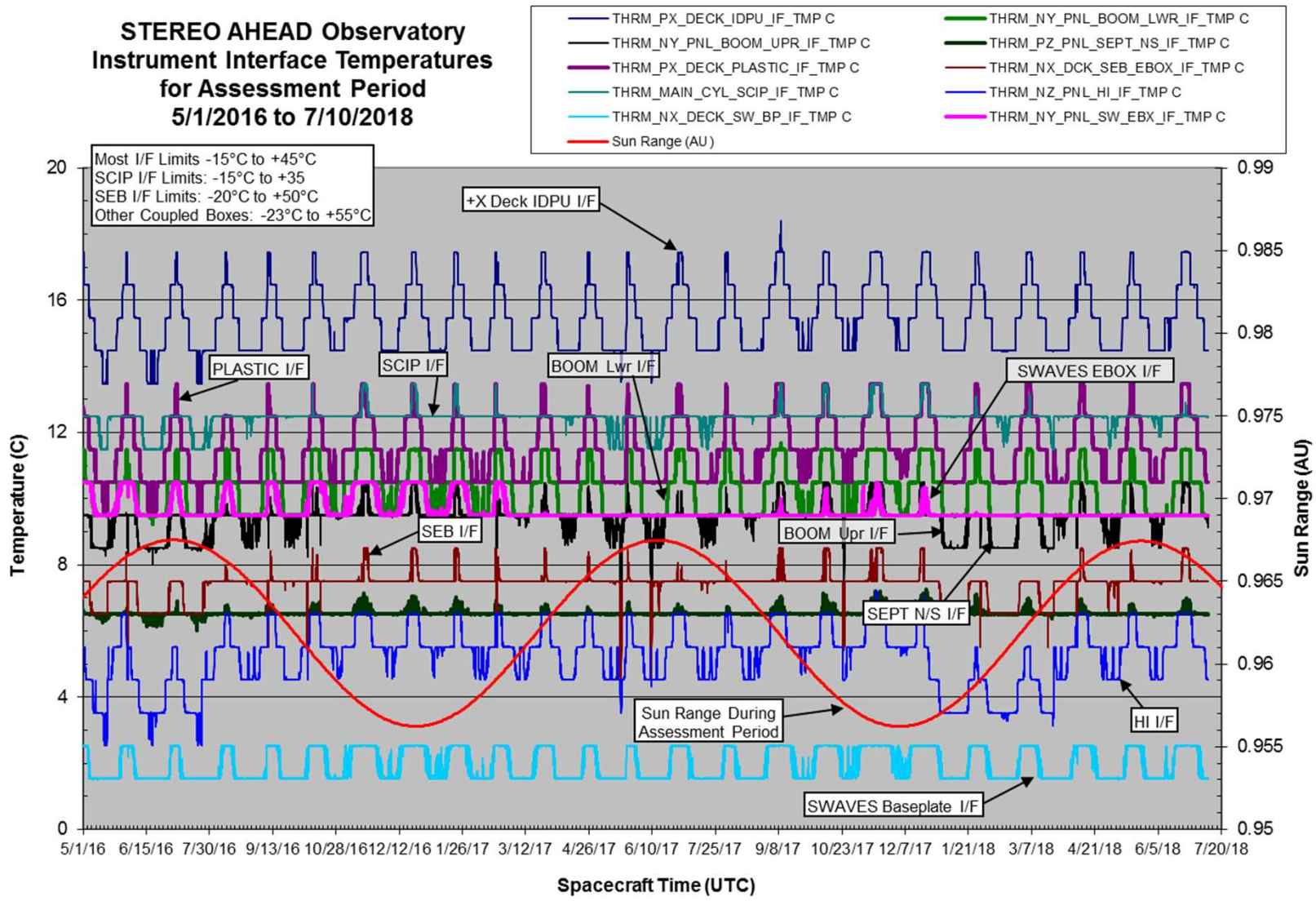
Thermal Subsystem Assessment



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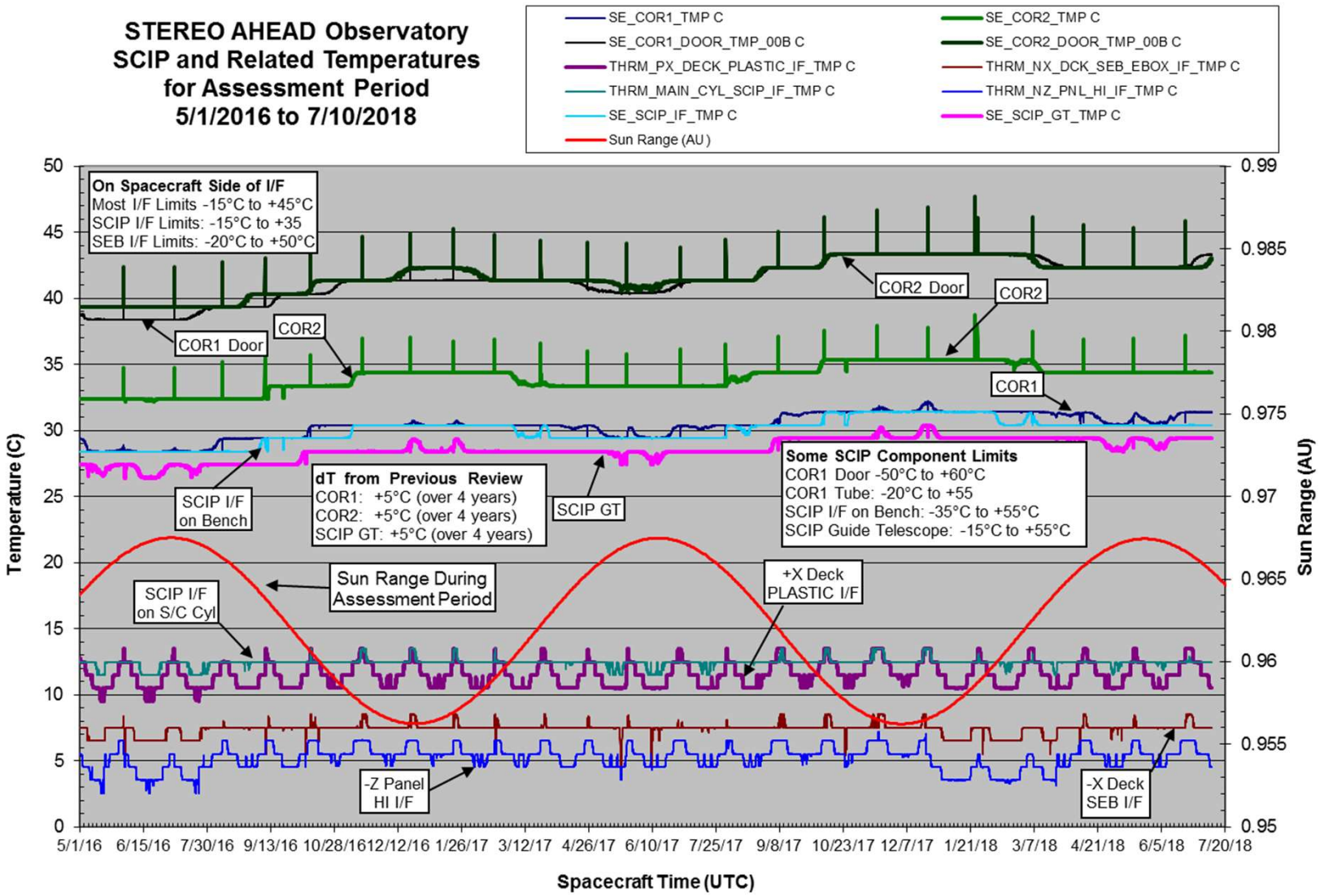
Thermal Subsystem Assessment



Space APL

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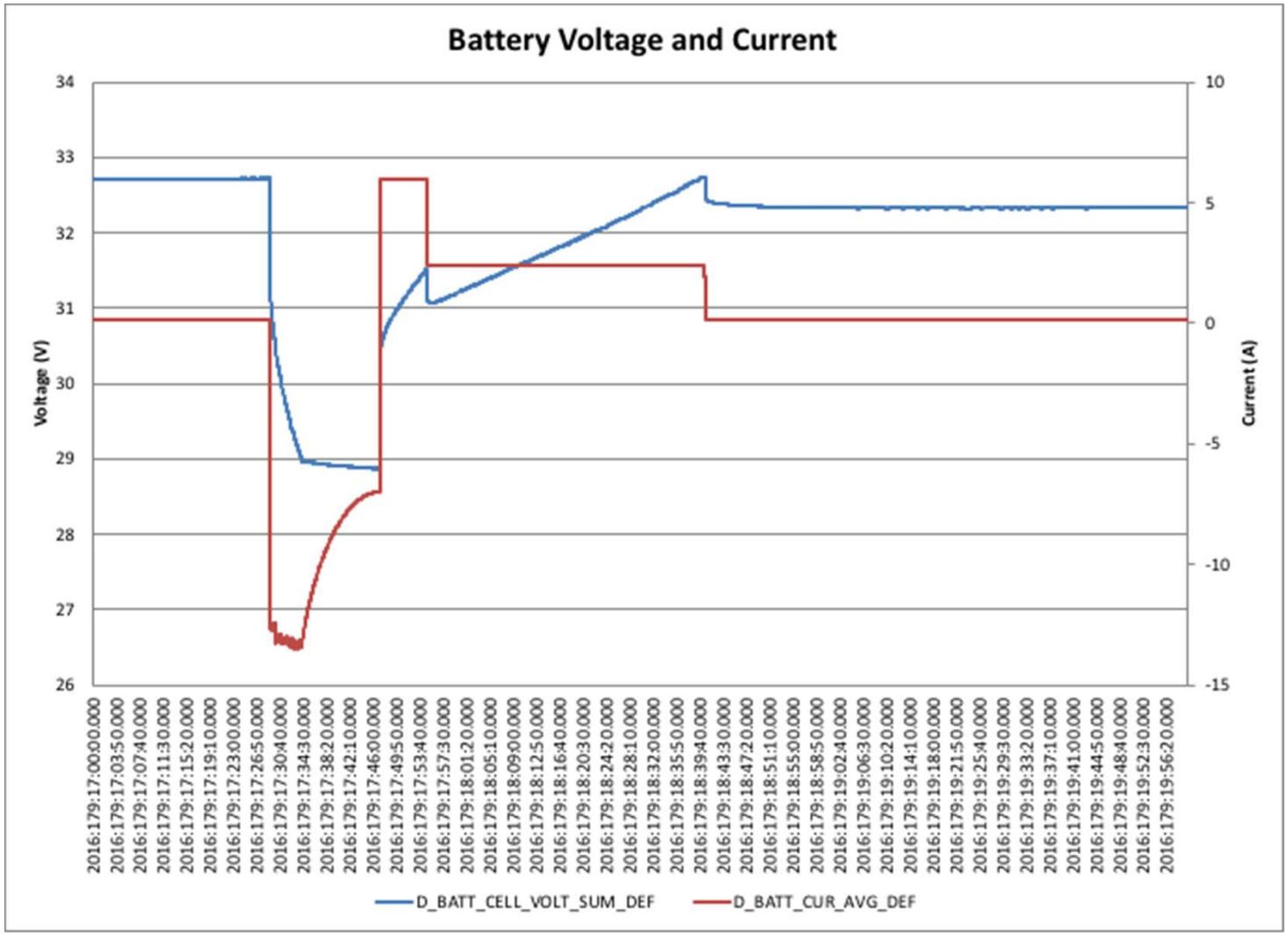
AGENDA

- STEREO AHEAD Battery Test
- STEREO AHEAD Power Trends
- Conclusion

AHEAD Battery Test

BATTERY DISCHARGE 2016



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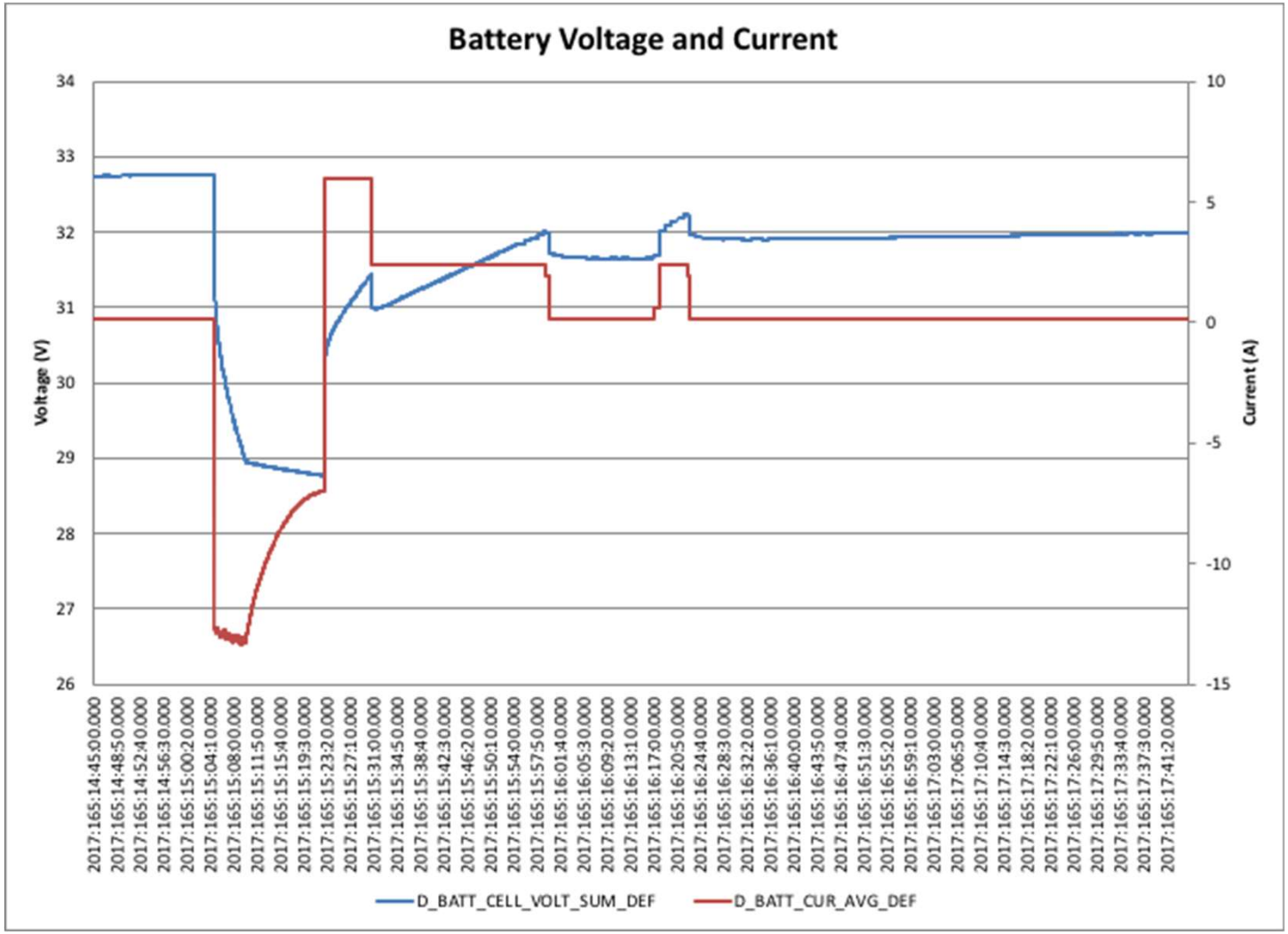
AHEAD Battery Test

BATTERY DISCHARGE 2017



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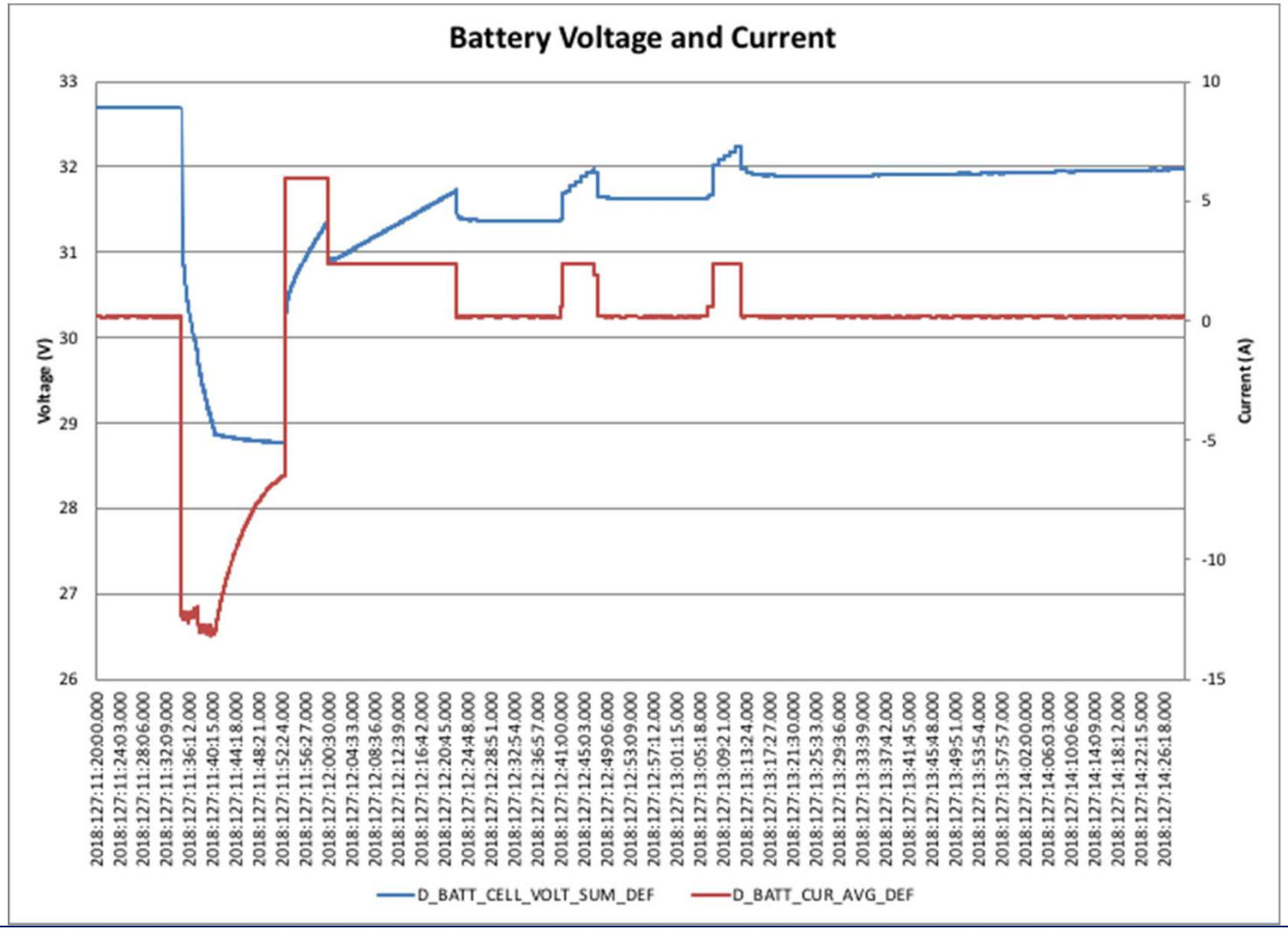
AHEAD Battery Test

BATTERY DISCHARGE 2018



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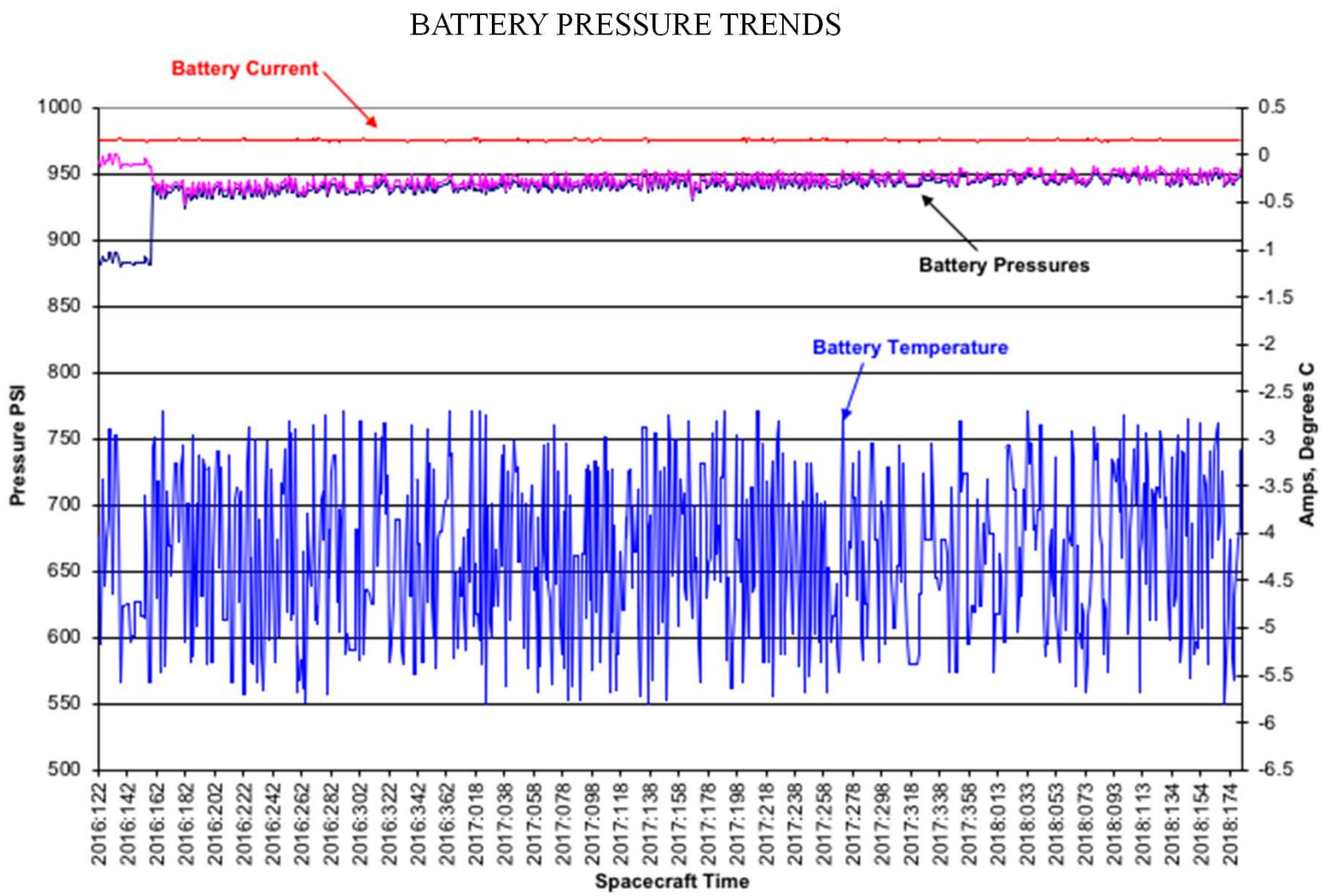
AHEAD Power Trends



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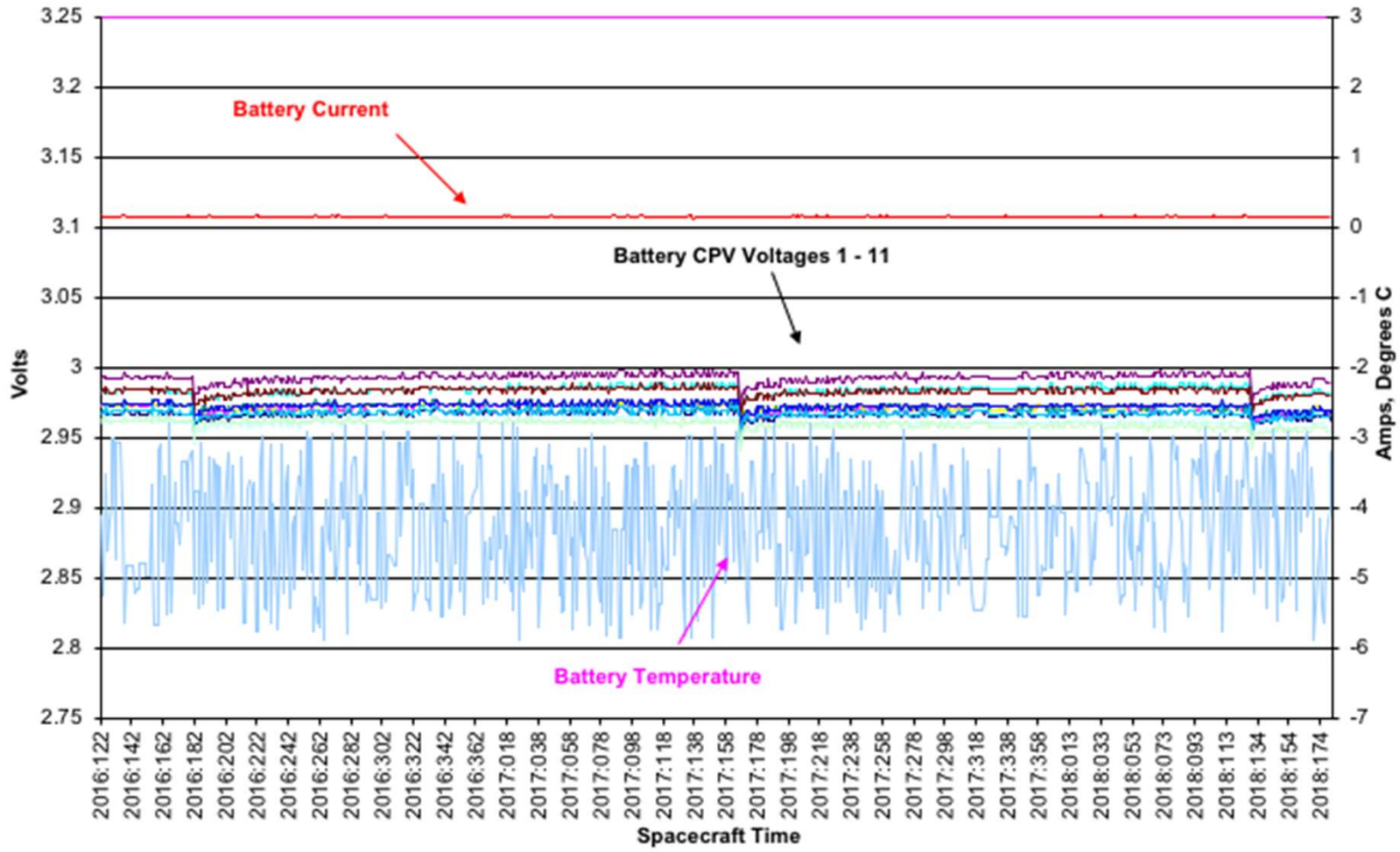
AHEAD Power Trends

BATTERY CELL VOLTAGE TRENDS



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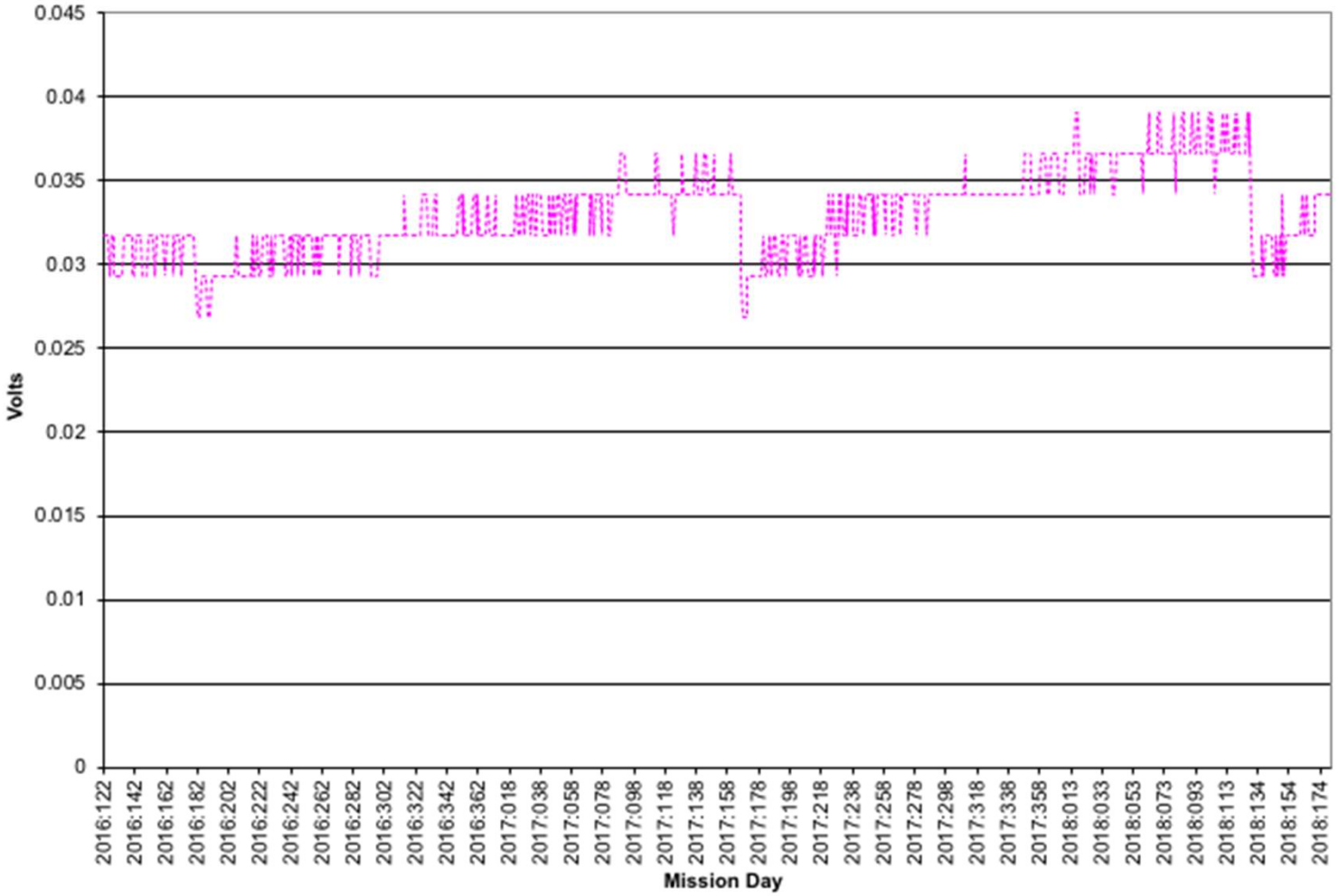
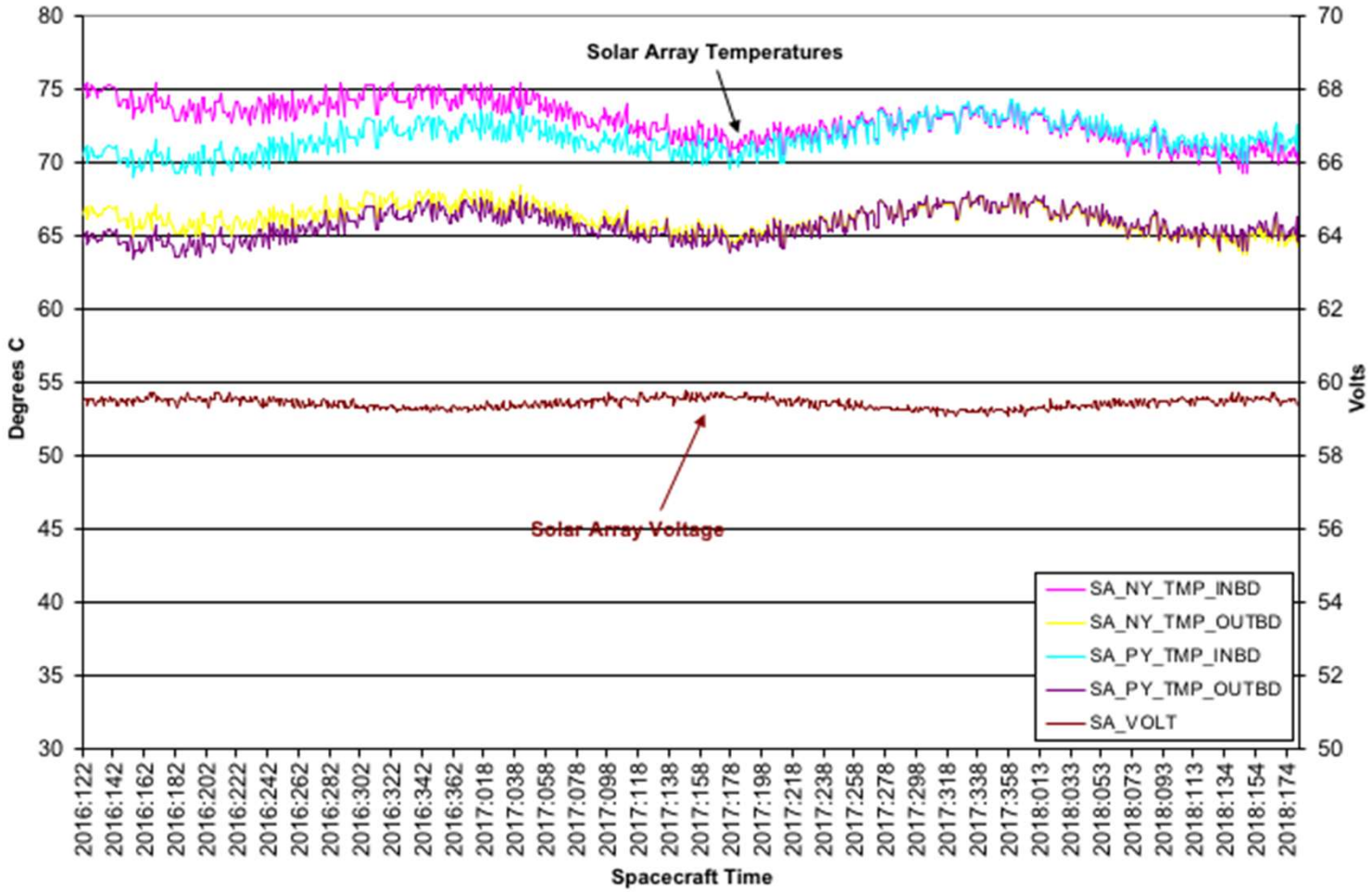
AHEAD Power Trends

BATTERY CELL DIFFERENTIAL VOLTAGE TRENDS



AHEAD Power Trends

SOLAR ARRAY VOLTAGE and TEMPERATURE TRENDS



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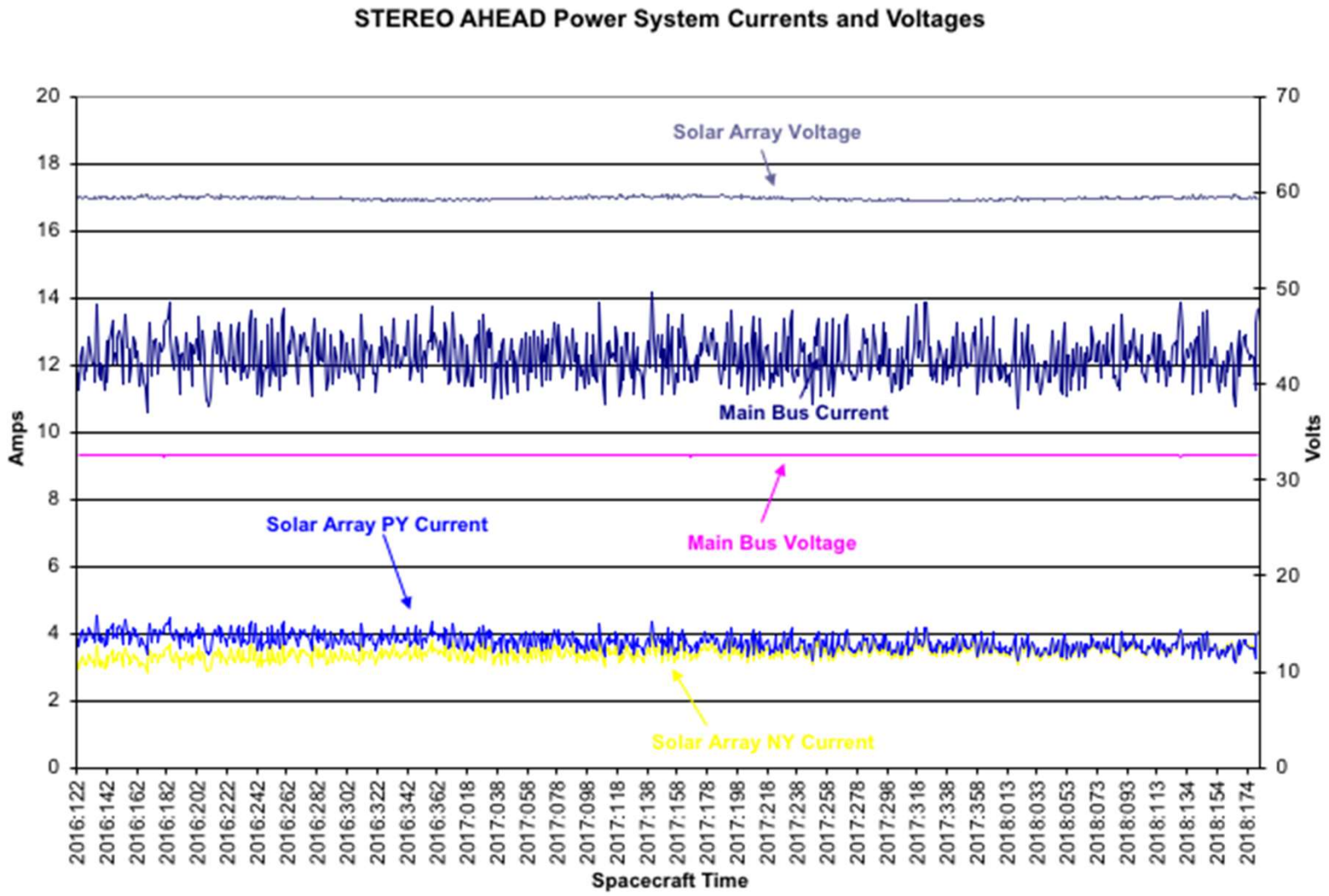
AHEAD Power Trends



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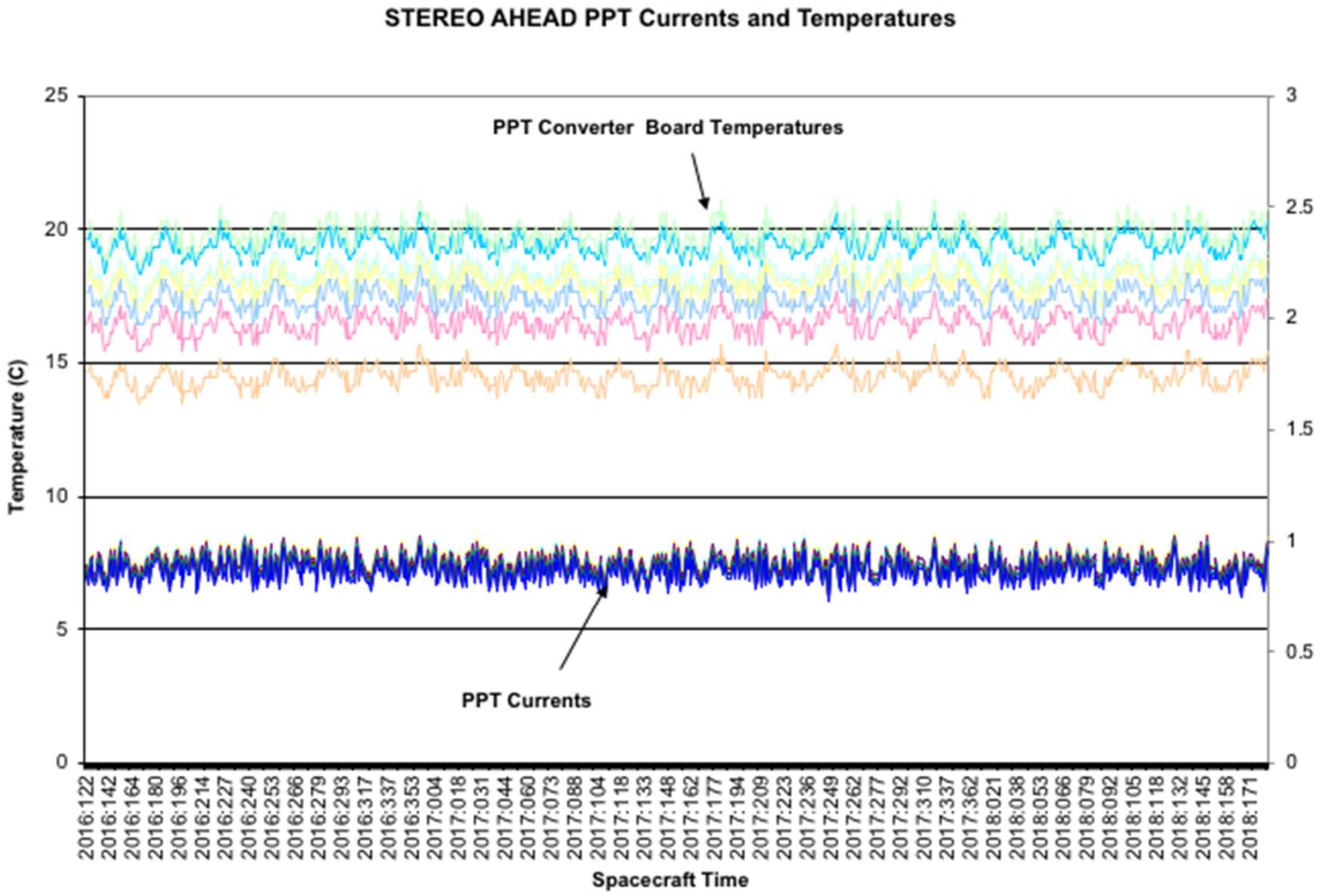
AHEAD Power Trends



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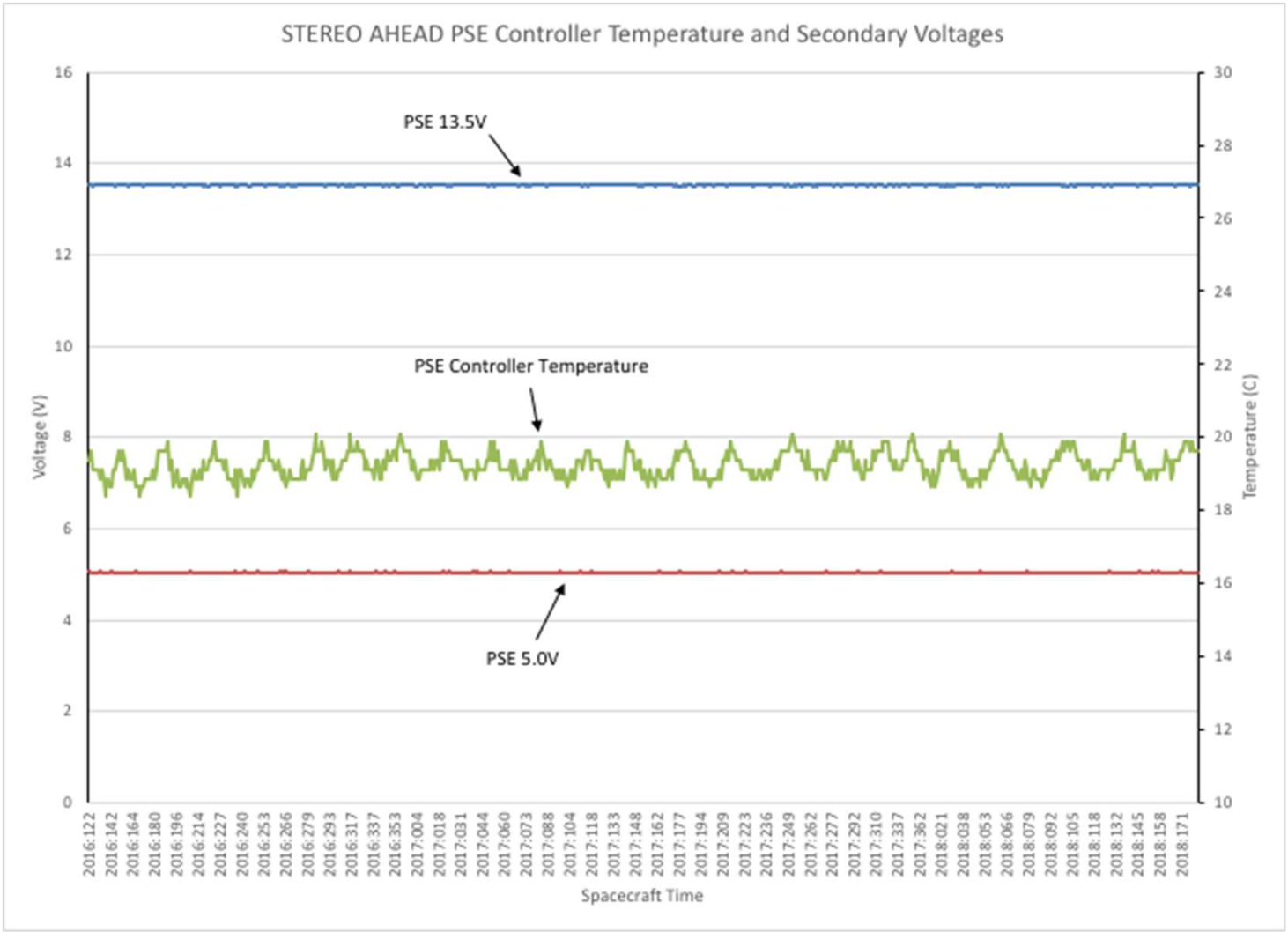
AHEAD Power Trends



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Conclusion

- PSE operating on the current controller loop as designed.
- Battery Pressures are trending as expected under trickle charge showing mainly temperature Variations.
- Battery Cell Voltages are showing temperature variations.
- Power System Bus Voltage and current is nominal.
- PSE Secondary voltages are nominal.

Note: Data shown in the slides is a small sample taken everyday at 00:00:00UTC.

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AGENDA

- Summary
- Uplink Parameters
- Downlink Parameters
- Voltage, Current, & Power Housekeeping
- Temperatures
- Closing

RF Summary

- RF Parameters continue to follow the trends previously documented by Matt Reinhart, Darryl W. Royster.
- Ahead RF communication subsystems continue to function as expected and well within parameter limits.

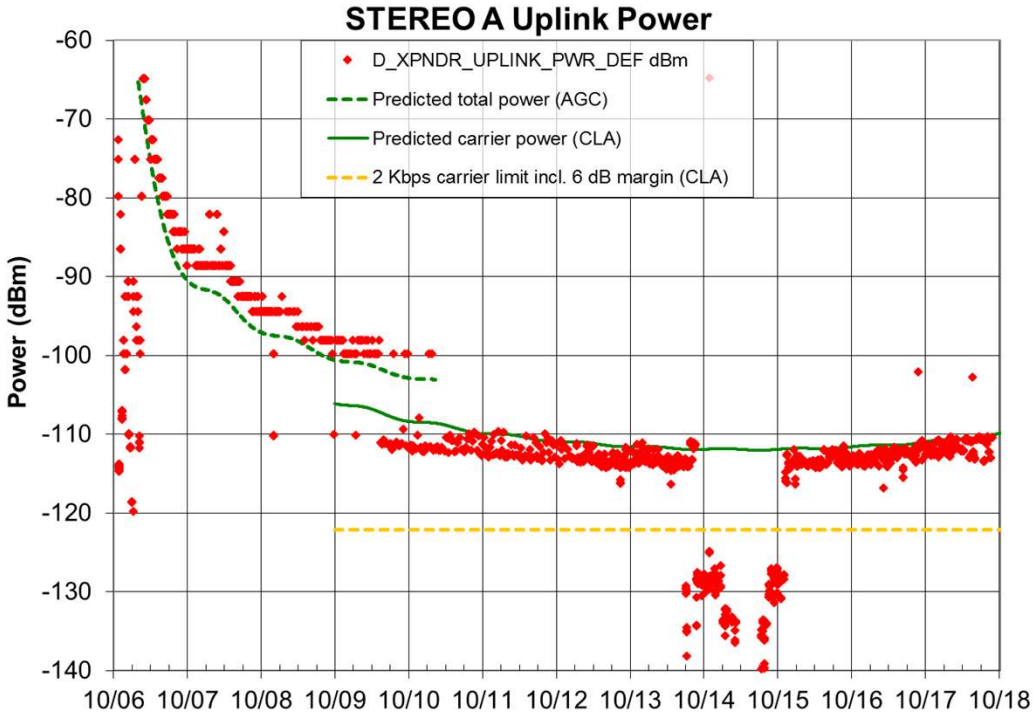
RF Links

- As the range is finally starting to decrease, the RF uplink and downlink grows less restrictive.
- For use with the Low Gain Antenna, ~~Ahead still requires at least a 70-meter antenna~~ (at 17 Kw) to close Emergency links (7.8 bps uplink and 12 bps downlink).
- As Ahead decreases from maximum range, LGA link margins continue to rise.
- The rest of this presentation focuses on the links between the High Gain Antennas and DSN stations.

Uplink Received Total Power

- Need > -116 dBm total power for 2 Kbps (with 6 dB margin).
- Need > -140 dBm total power for 7.8 bps (with 6 dB margin).
- Uplink power shifts from total power (AGC telemetry) to carrier power (CLA telemetry) at -110 dBm.
- Good correlation with predicts, plenty of margin

(DSN is using only 10 Kw which is 2.4 dB lower than predicted maximum uplink power.)



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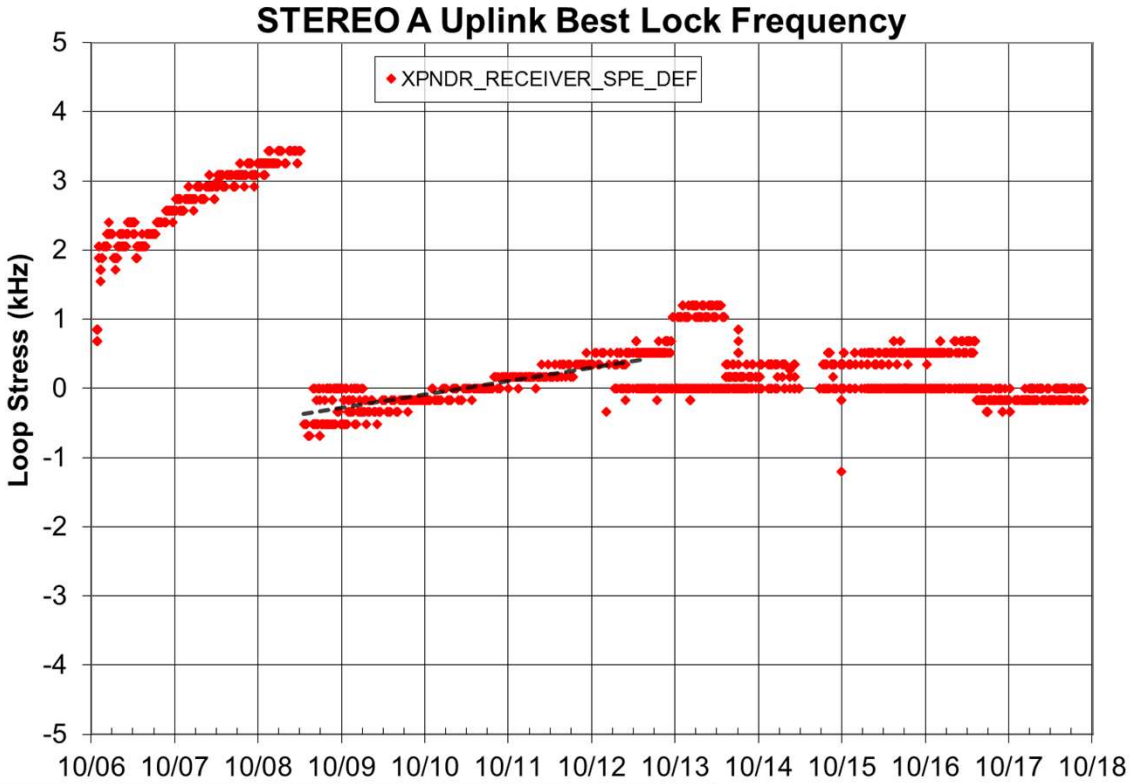
Uplink Best Lock Frequency
(reported as Static Phase Error - SPE)



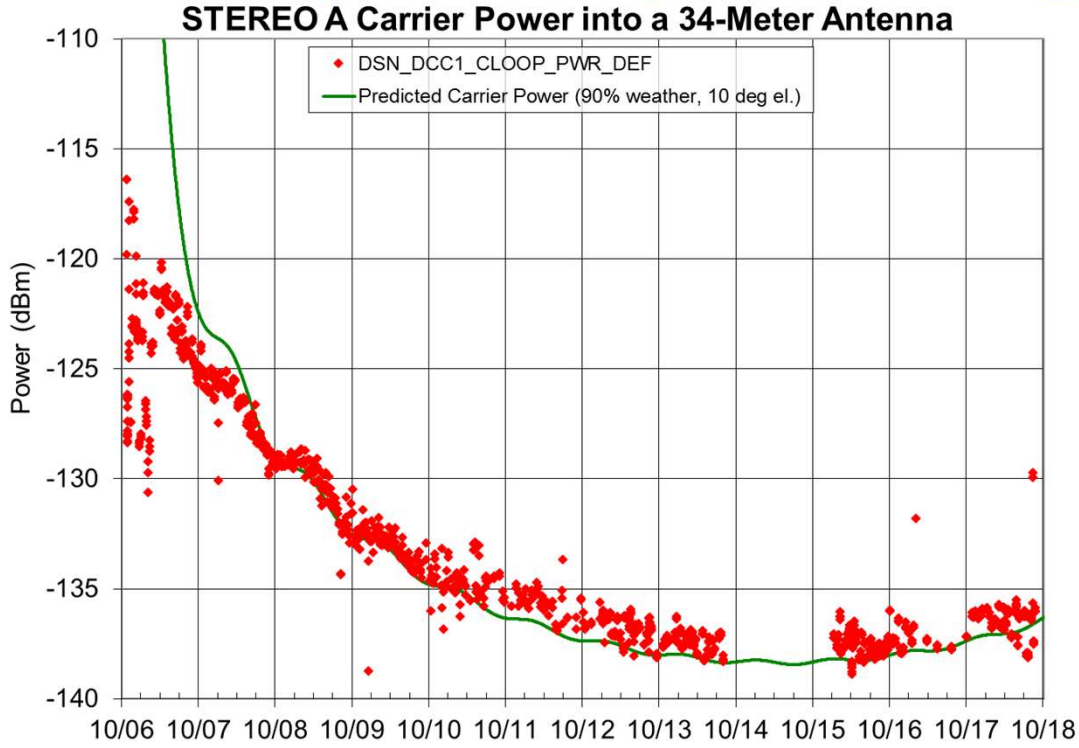
Best Lock Frequency	STEREO-A
As measured prior to launch	7,186,583,000 Hz
As measured by DSN on 8 April 2009	7,186,578,900 Hz
As measured by DSN on 2 Jan 2012	7,186,577,700 Hz
As measured by DSN on 28 Sep 2014	7,177,323,918 Hz
Latest BLF for DSN	7,186,577,940 Hz ***

*** Value currently used by the DSN for uplink acquisition.

Downlink Received Carrier Power (34 m)

Spacecraft HGA into DSN 34-Meter Ground Station

- Need > -136 dBm carrier power for 240 Kbps (with 2 dB margin)
- Need > -137 dBm carrier power for 160 Kbps
- Need > -139 dBm carrier power for 120 Kbps
- Need > -165 dBm carrier power for 12 bps (with 3 dB margin)



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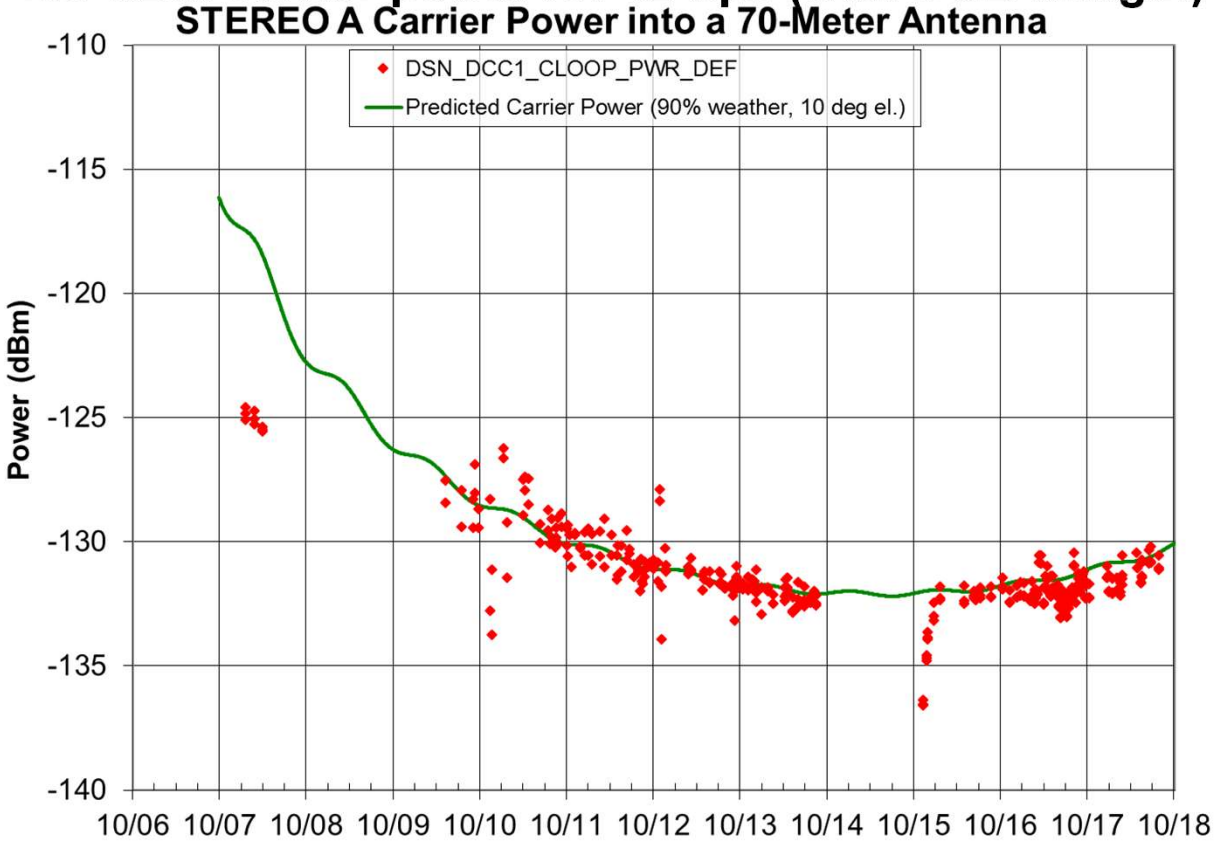
Downlink Received Carrier Power (70 m)

Spacecraft HGA into DSN 70-Meter Ground Station

- Need > -131 dBm carrier power for 720 Kbps
- Need > -133 dBm carrier power for 480 Kbps
- Need > -165 dBm carrier power for 12 bps (with 3 dB margin)



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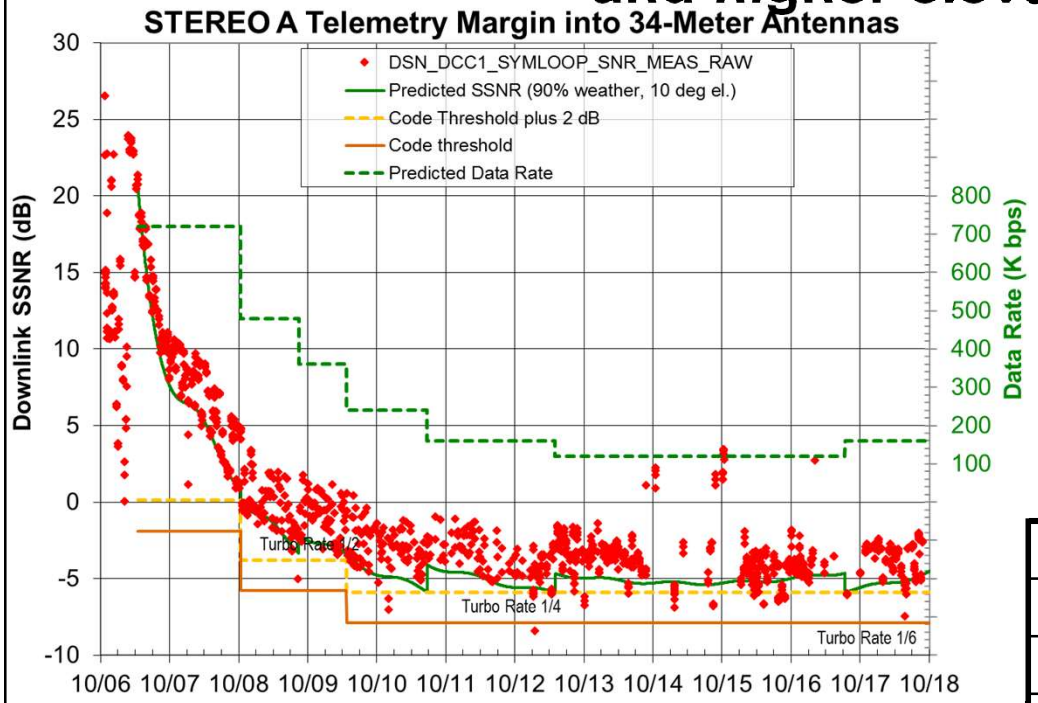
Downlink Symbol Signal to Noise Ratio (34 m) (SSNR)

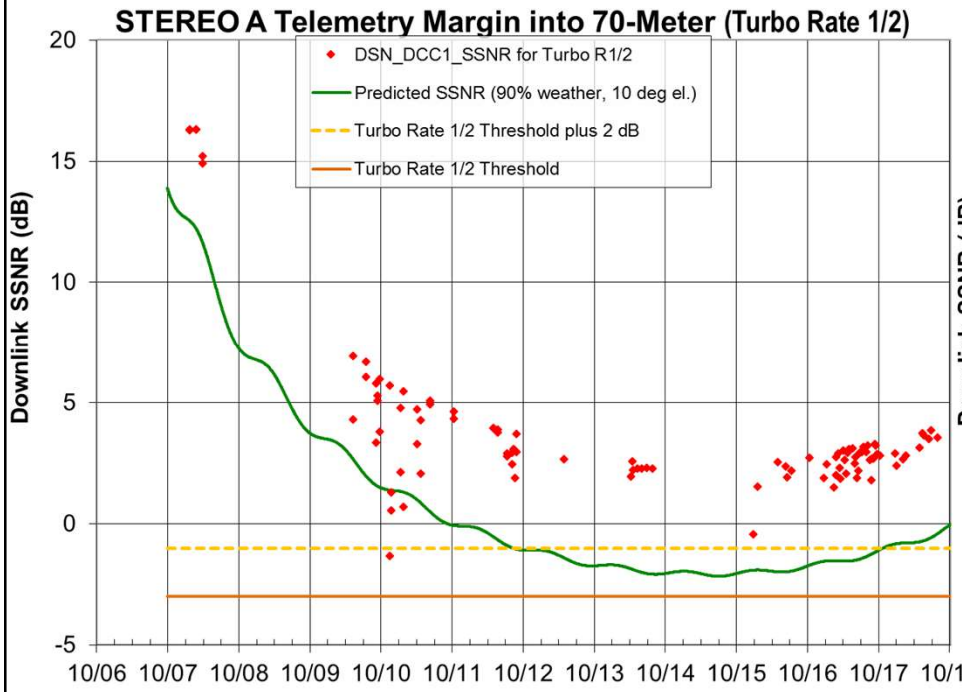
Observations closely follow predicted performance for lower and higher elevation tracks.

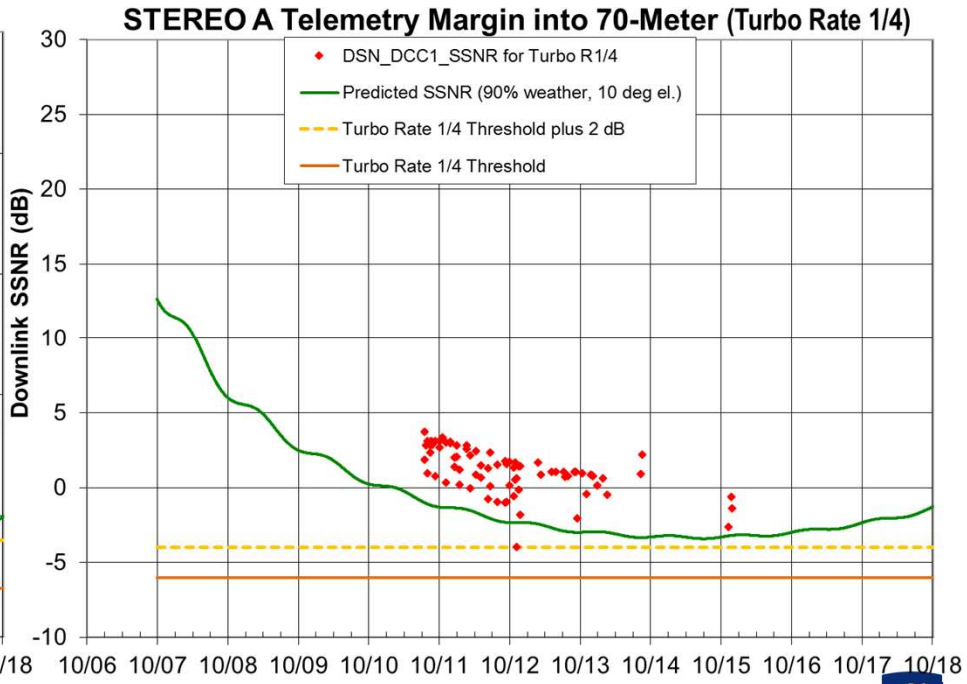


Rate Change	STEREO-A
720K (R1/2) to 480K (R1/4)	13 Oct 2008 actual
480K (R1/4) to 360K (R1/4)	17 Aug 2009 actual
360K (R1/4) to 240K (R1/6)	26 Apr 2010 actual
240K (R1/6) to 160K (R1/6)	27 June 2011 actual
160K (R1/6) to 120K (R1/6)	29 April 2013 actual
Sidelobe Operations	Aug 2014- Nov 2015
160K (R1/6)	~ Dec 2015-present
160K (R1/6) to 240K (R1/6)	1 Feb 2019 estimated

Downlink Symbol Signal to Noise Ratio (70 m)

Decided to use only 720kbps D/L rate for all 70m tracks for post Sidelobe Operations. Performance is following updated predictions.





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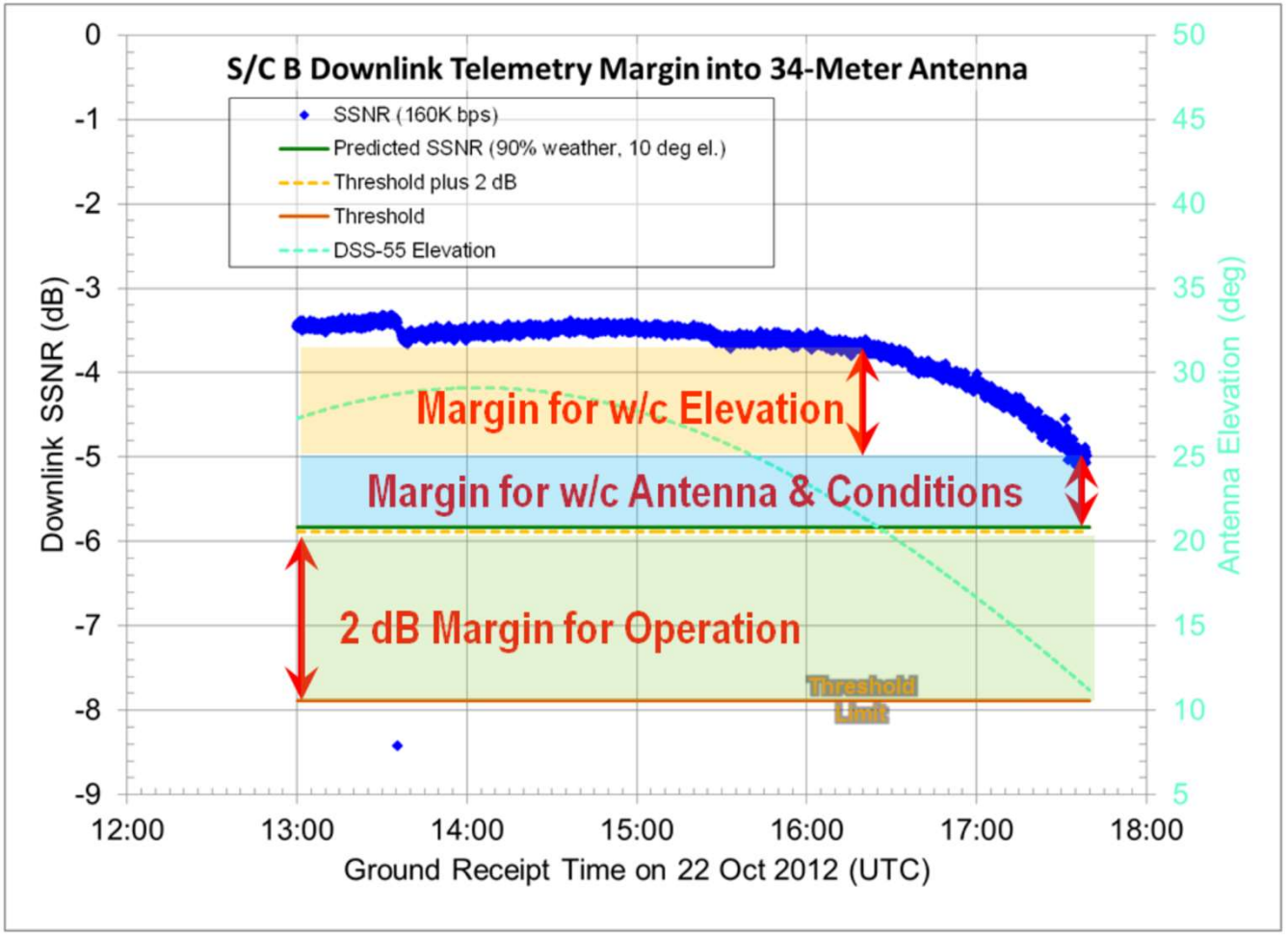
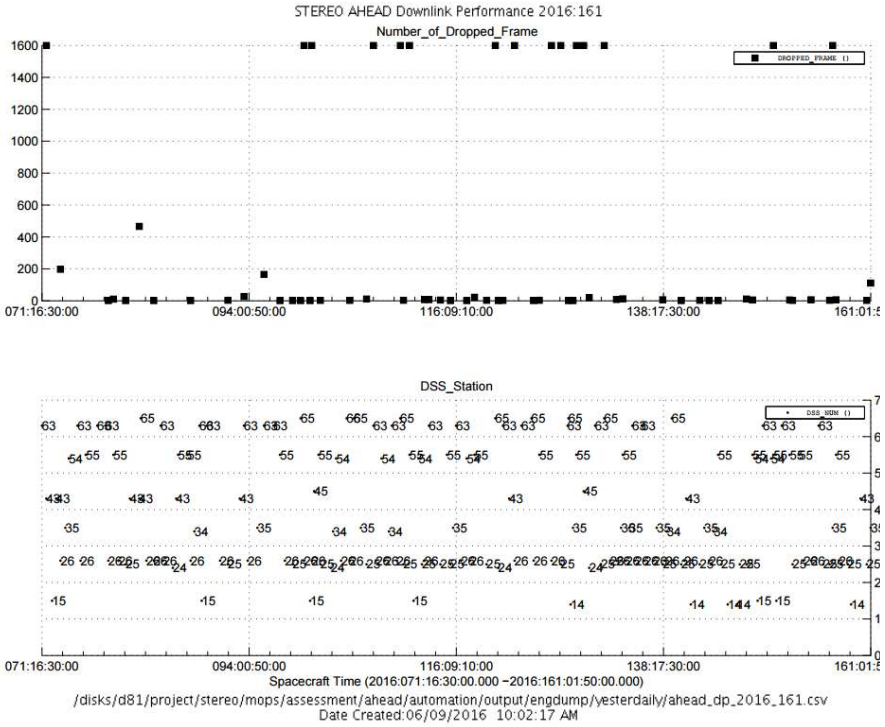
Predicts Include Worse Case Margins

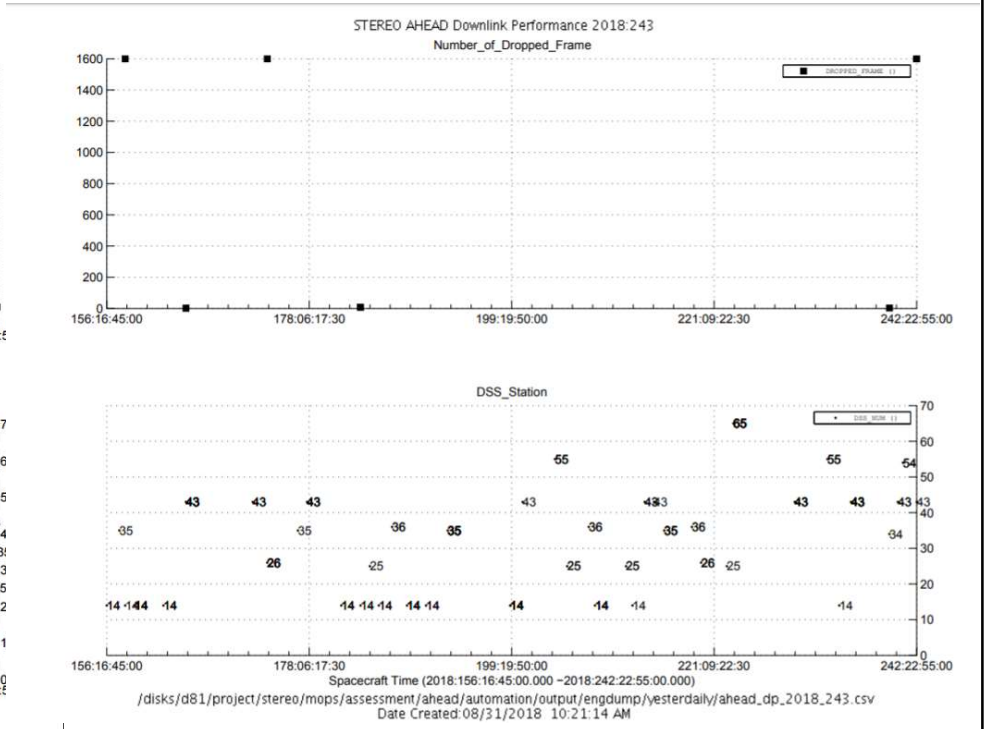


We have moved to a more realistic margin model in recent years.
This has worked extremely well, and allowed for a much larger data volume.

Dropped Frames Have Greatly Improved



2016



2018

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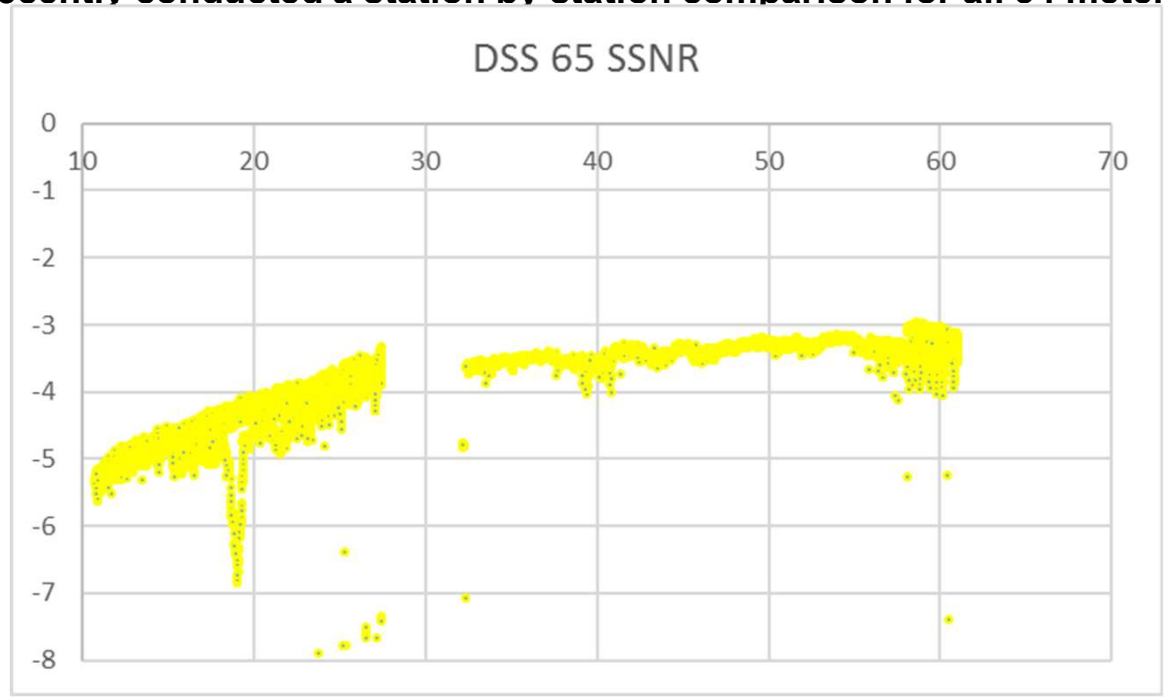
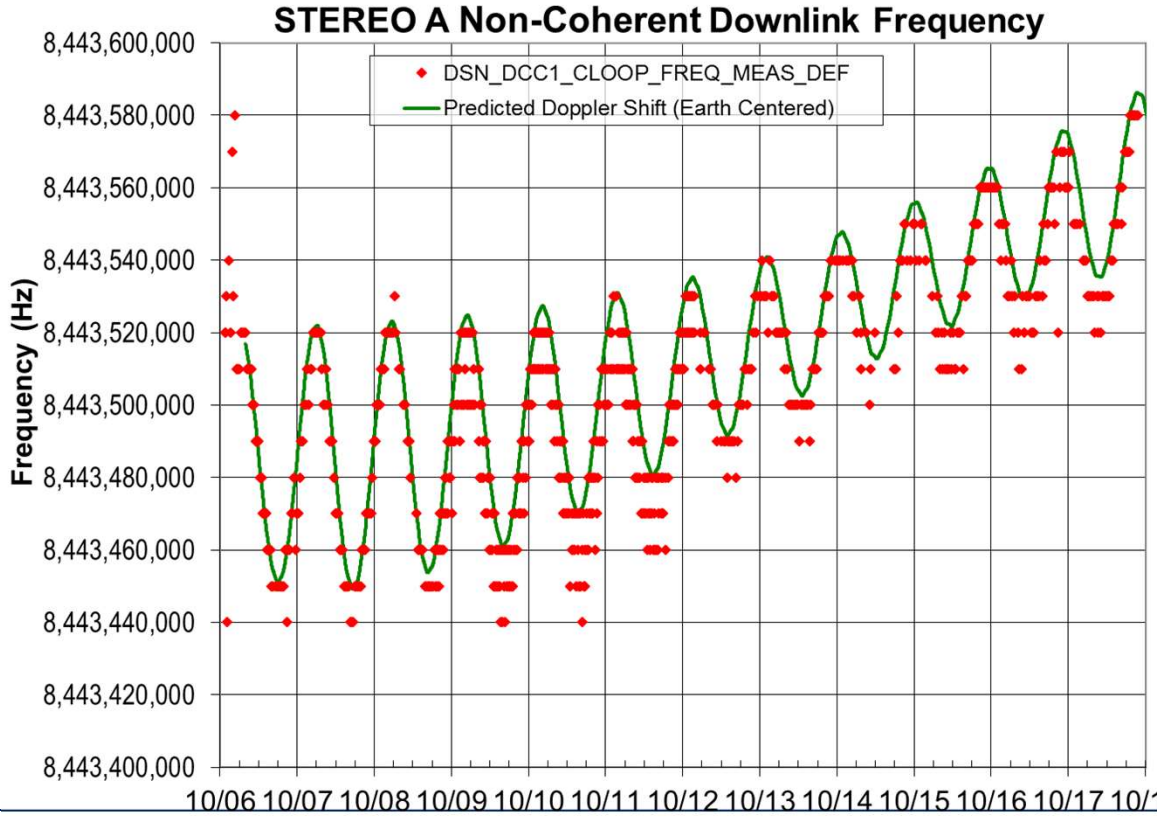
Telemetry Observations

- **Dropped Frame issue:**
  - **Problem has improved**
- **Continue to adjust rates for stations and elevations as appropriate:**
  - **Upgrades to DSS 25 now has same performance as DSS 26**
  - **Recently conducted a station by station comparison for all 34 meter stations**



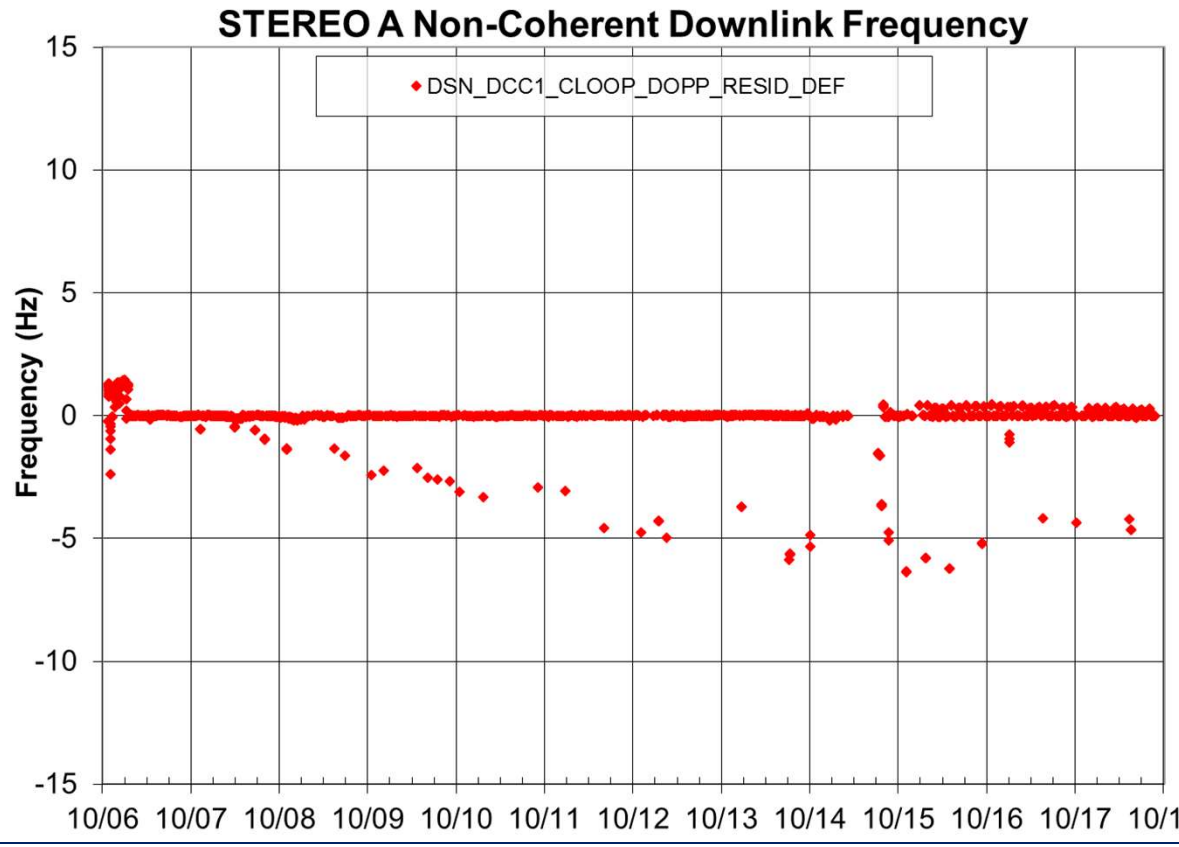
Downlink Unlocked Carrier Frequency

- Knowledge aids 1-way (or non-coherent) downlink carrier acquisition.
- Gradual oscillator shift with age and temperature is normal.
- Observed data dominated by seasonal Doppler variation (Earth range).
- Observed variation is consistent with existing trends.



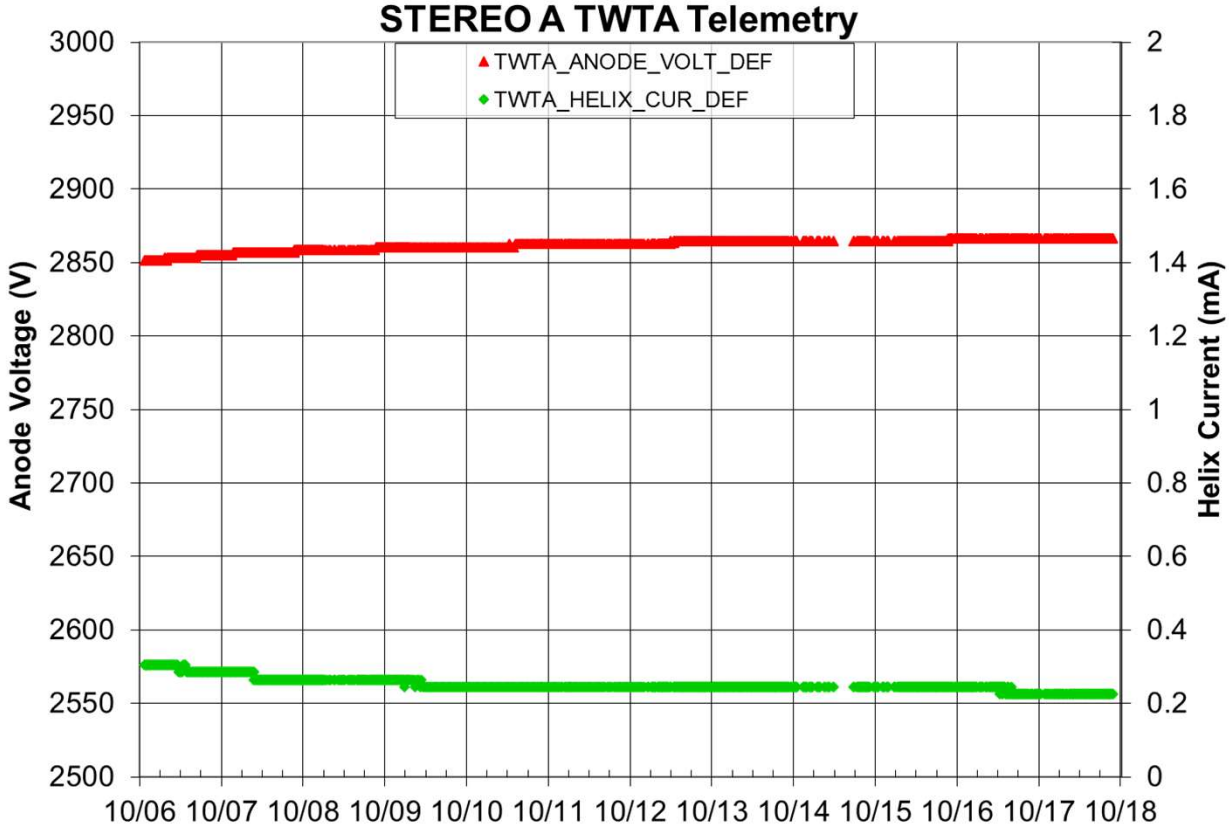
Downlink Doppler Residual Frequency

- Provides measure of Doppler predict accuracy and coherency verification
- Consistently good (near zero)



TWTA Anode Voltage and Helix Current

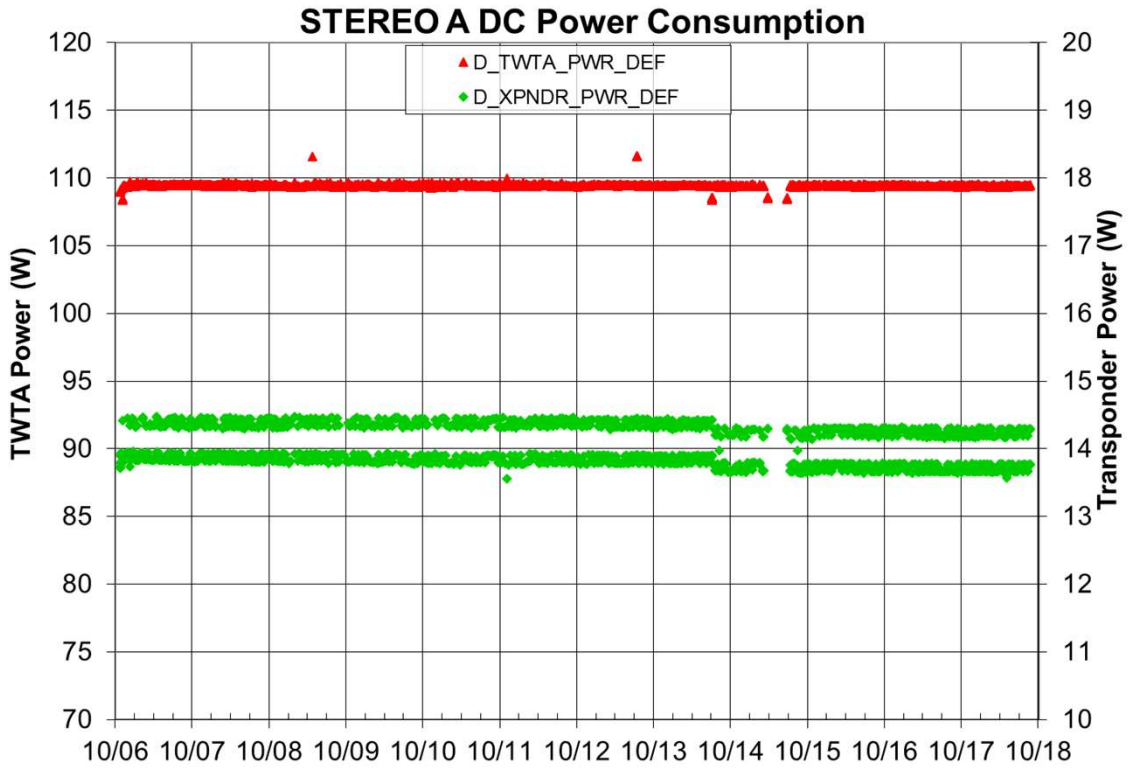
- Provides TWTA state of health
- Anode voltage should be < 3000 V
- Helix current should be < 2 mA



TWTA - Travelling Wave Tube Amplifier

TWTA and SDST Primary Power Draw

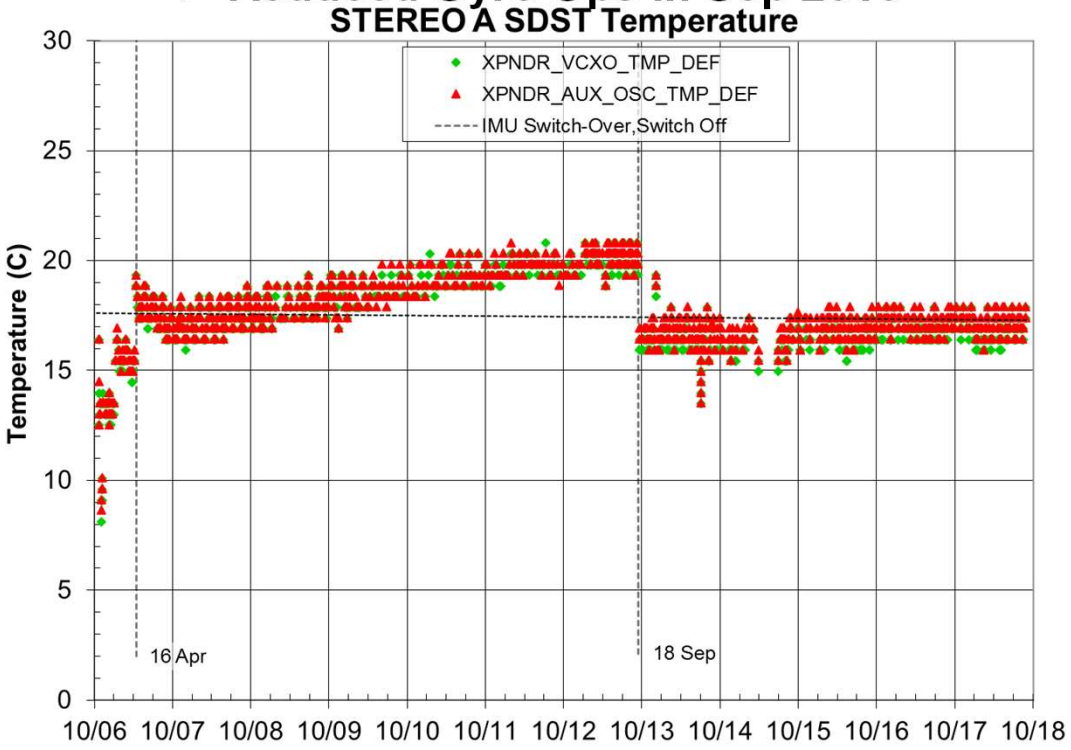
- **TWTA specified power limit is < 116 W**
- **SDST specified power limit is < 15.4 W**
  - **Two states observed for locked and unlocked uplink**



SDST – Small Deep Space Transponder

Transponder VCXO and Aux. Osc. Temperature

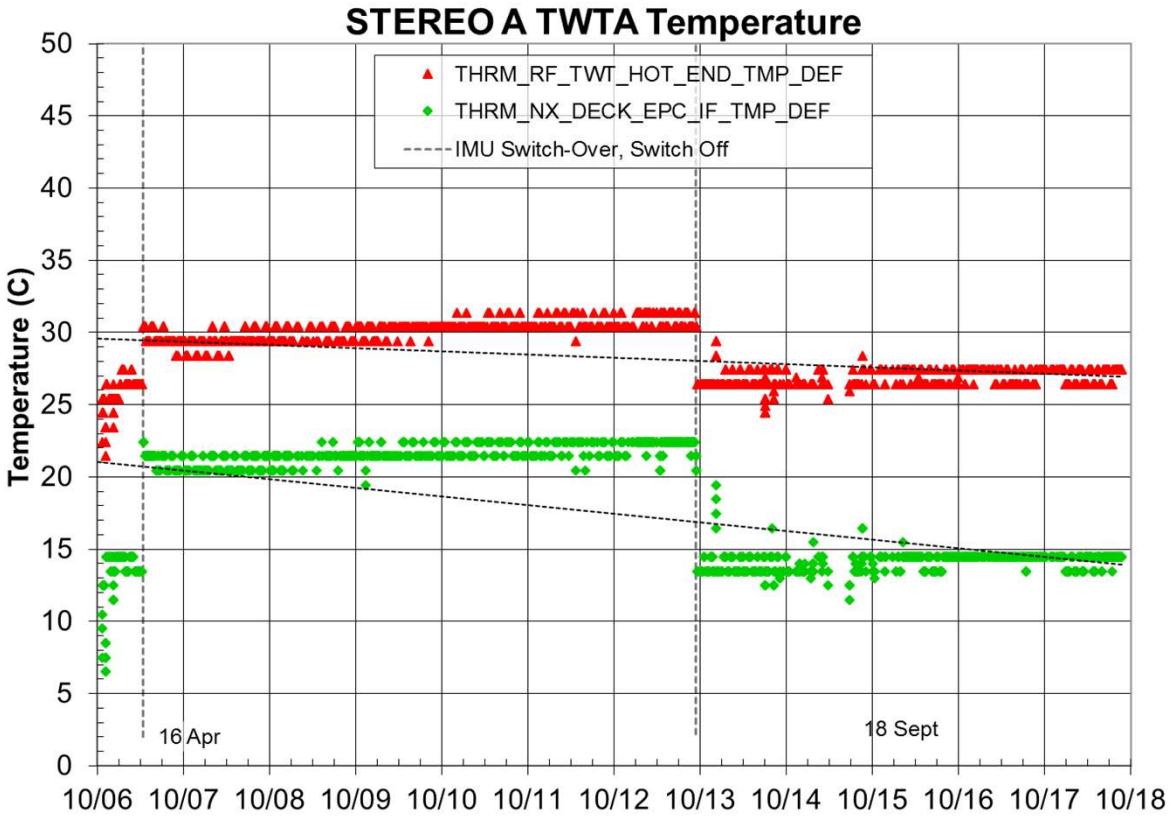
- Gradual increase of ~4 °C since launch until move to Reduced Gyro Ops
- Well within preferred range of 0 °C to 40 °C
- Observed steps coincide with IMU changes
  - Switch-Over in April 2007
  - Reduced Gyro Ops in Sep 2013



VCXO – Voltage Controlled Crystal Oscillator

TWTA Temperature

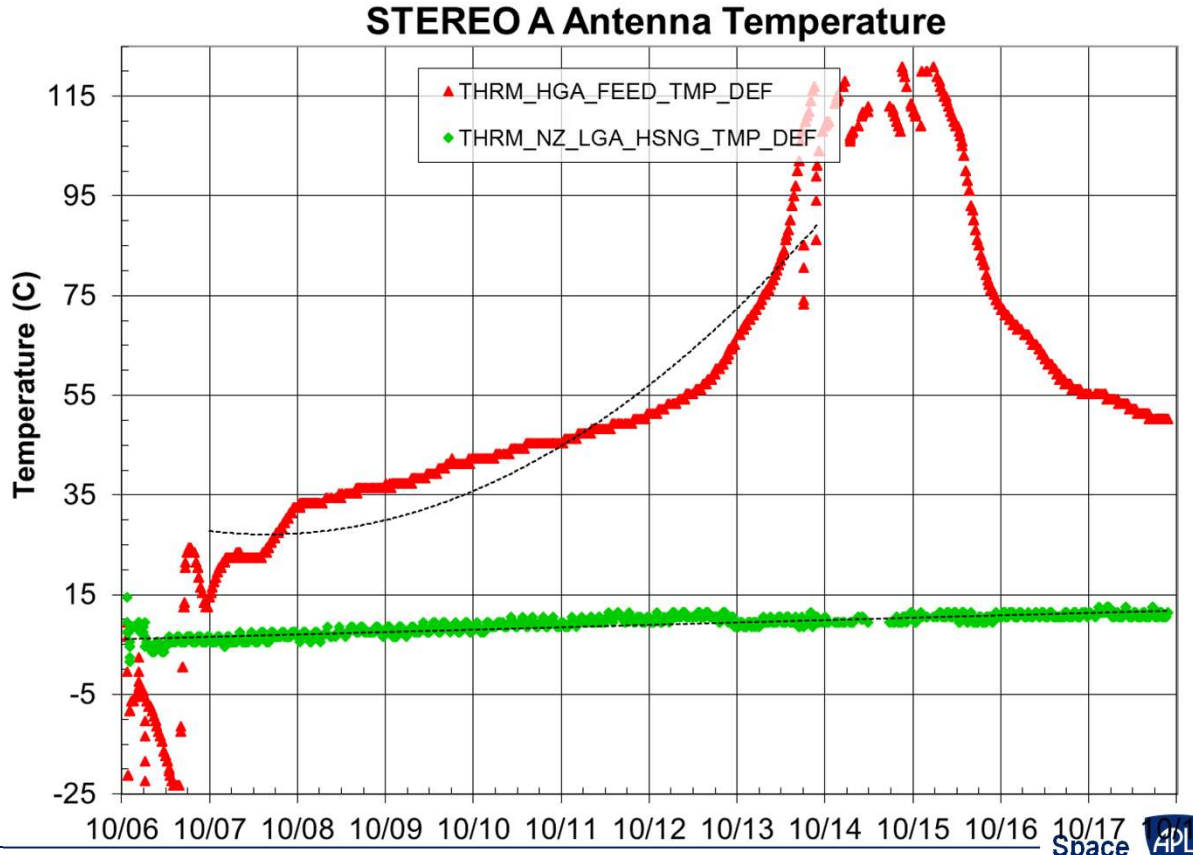
- Provides indication of operating environment
- TWT well within spec. range of -25 °C to +80 °C
- EPC well within spec. range of -25 °C to +65 °C



EPC – Electronic Power Conditioner
TWT – Travelling Wave Tube

Antenna Temperatures

- Provides indication of operating environment
- HGA feed almost back within spec. range of -130 °C to +90 °C
- Negative Z LGA well within spec. range of -90 °C to +90 °C
- Highly dependant on sun-probe-earth angle on antenna



HGA – High Gain Antenna
LGA – Low Gain Antenna

Closing Comments

- The RF communication subsystems for Ahead continue to function as expected and well within parameter limits.
- Link observations closely follow MOPS predicted performance based on elevation and station
- 70-m Telemetry was increased to 720K bps by design for all passes regardless of elevation.
- Temperatures for the Transponder, EPC and TWT have increased slightly but are well within limits.
- Continue to choose D/L Rates on a station by station and elevation determination.

STEREO Propulsion Subsystem

19 September 2018

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Introduction

- The STEREO Propulsion Subsystems are blowdown monopropellant designs.
- Each spacecraft, at launch, was loaded with 62.2 kg of hydrazine.
- The current usable propellant load, measured by PVT, is:
  - 39.55 ± 0.45 kg on S/C A (vs. 40.84 ± 0.44 kg @ 2016.06.15 Trending Review)
  - 42.34 ± 0.43 kg on S/C B (As of 30 September 2014)
- Milestones:
  - Momentum dumps between 1 May 2016 and 30 June 2018:

S/C A		
MD 88: 2016.05.31	MD 97: 2017.03.22	MD 106: 2018.01.25
MD 89: 2016.07.06	MD 98: 2017.04.24	MD 107: 2018.03.05
MD 90: 2016.08.09	MD 99: 2017.05.22	MD 108: 2018.04.10
MD 91: 2016.09.08	MD 100: 2017.06.29	MD 109: 2018.05.15
MD 92: 2016.10.10	MD 101: 2017.07.31	MD 110: 2018.06.21
MD 93: 2016.11.16	MD 102: 2017.09.06	
MD 94: 2016.12.20	MD 103: 2017.10.09	
MD 95: 2017.01.19	MD 104:	

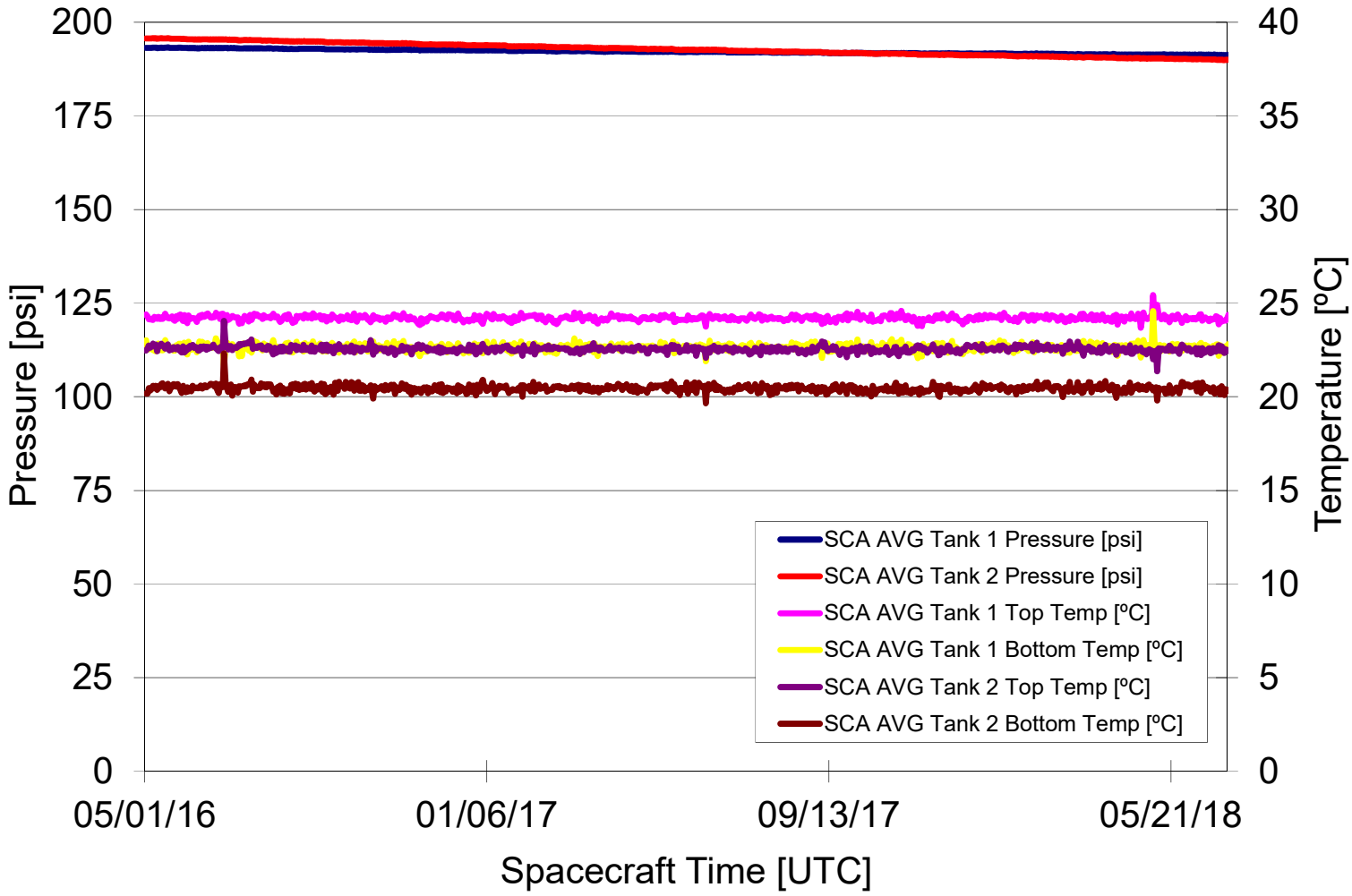
  - These maneuvers u[illegible]8 g N_2H_4 on S/C A.

Open ARs/PFRs

- None.

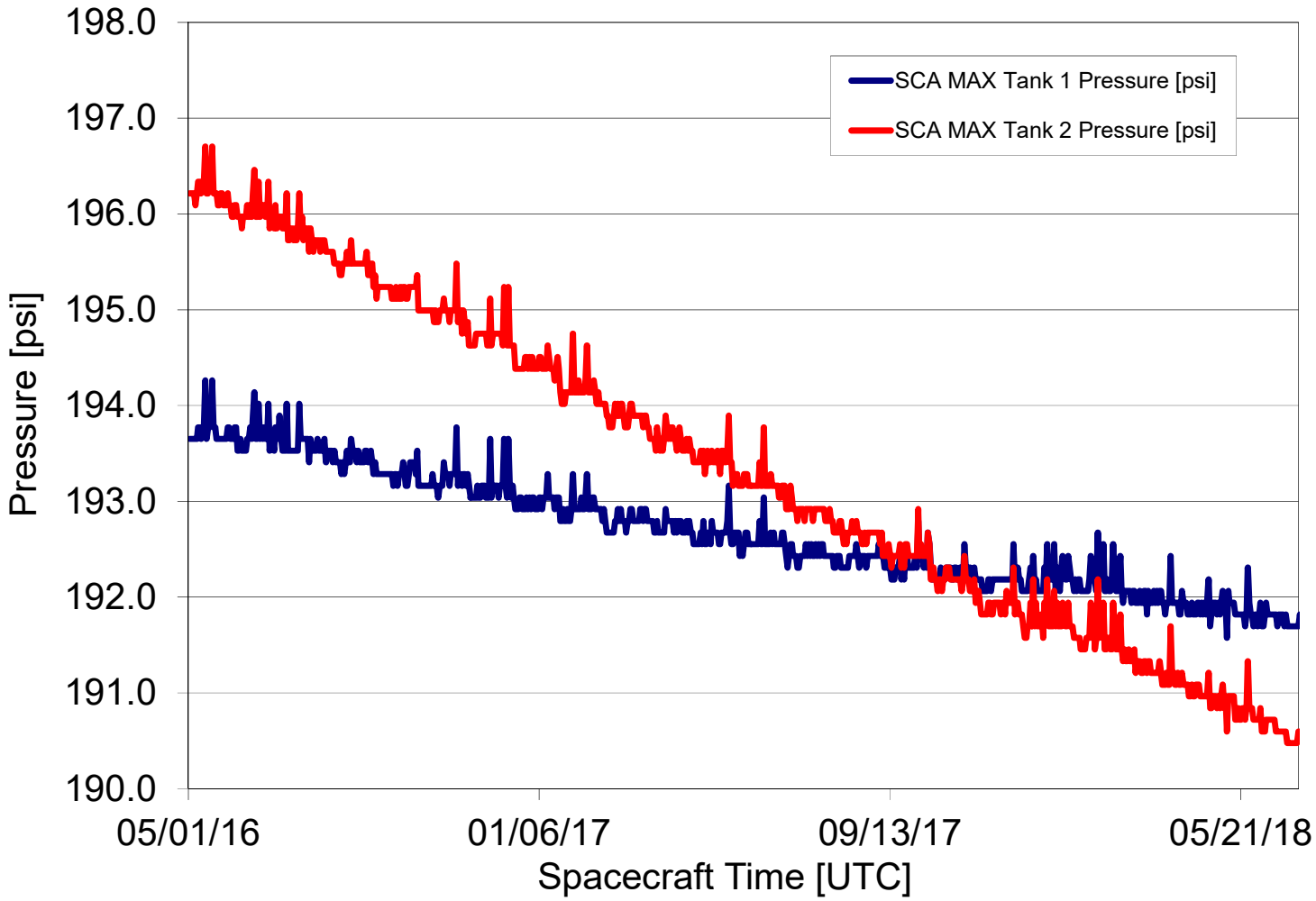
Subsystem Performance – SCA Tanks

- Pressures and temperatures are within nominal ranges.



Subsystem Performance – SCA Tanks

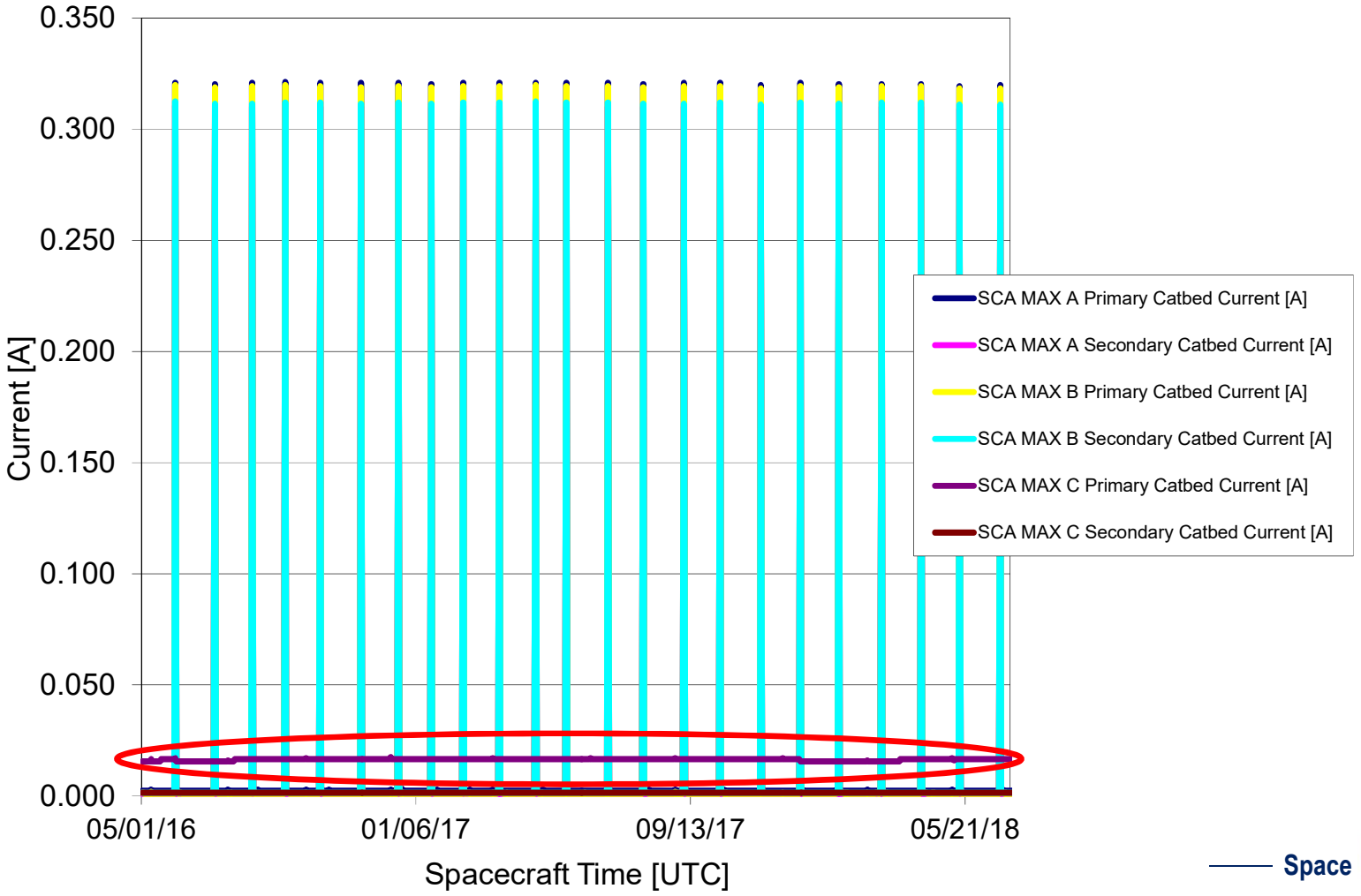
- MAX Data shows Pressure Spikes related to Water Hammer



Space APL

Subsystem Performance – SCA Catbeds

- Each catbed current is the total of four catbeds wired together, nominal current for one catbed is 75 mA (400Ω/30V Bus); therefore while in operation current should read ~300 mA.
- Circled data, corresponding to SCA C Primary Catbed Current ≈ 20 mA, per AR ST-2122



Anomalies/Anomalous Trends

- None.

Conclusions

- **The STEREO Propulsion Subsystem has performed nominally since launch, and it continues to support regular momentum dump maneuvers.**