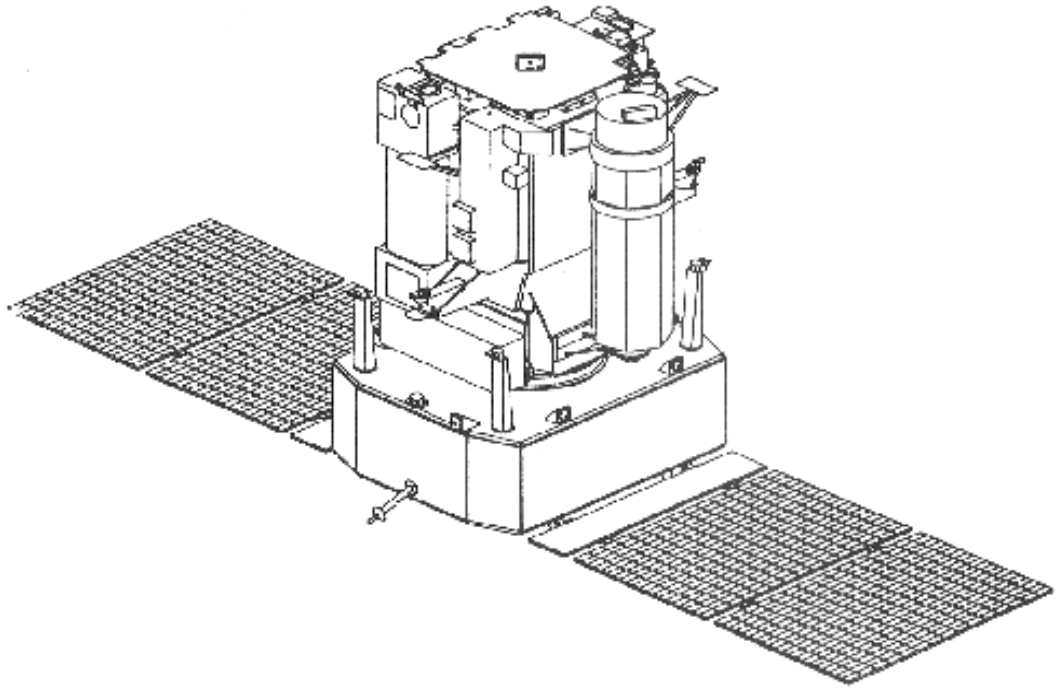
Goddard Space Flight Center, Greenbelt

SOHO
ESR 27-28-29 and Warm StartUp Report (May 2012)

Ref: SOHO/PRG/RP/743 Iss 1 2012 May 31



Prepared by: JP. OLIVE (EADS ASTRIUM)
T. V. OVERBEEK (ESA)

Approved by: B. FLECK (ESA)

Table of Contents

1 Introduction

This document reports about the successive ESR's SOHO experienced between May 4 and 9 2012.

The report is articulated in three parts:

1- description of the ESR's and first results of investigation on these major anomalies;

2- overall sequence of events, presenting timing of both anomalies and execution of recovery scripts/procedures and maneuvers

3- summary and major points about spacecraft behavior during the whole recovery sequence.

The previous three ESR occurrences:
- ESR-24 on Dec-8 2004,
- ESR-25 on July 12 2009,
- ESR-26 on Aug 20 2010)

were also caused by a false triggering of CSPAAD.
For more information see RD1, RD2 and RD3.

Since April 2004, the FSPAAD (Fine Sun Pointing Anomaly Detector) has been declared faulty and therefore is not used for failure detection.

2 Reference documents

[RD1] ESR-24 Report Ref: SOHO/PRG/RP/602 Dec 8, 2004
[RD2] ESR-25 Report Ref: SOHO/PRG/RP/696 July 15, 2009
[RD3] ESR-26 Report Ref: SOHO/PRG/RP/718 Sep 3, 2010
[RD4] FPSS, SAS1-A and SAS1-B comparison during ESRs 27, 28 and 29
Ref: SOHO/PRG/RP/746 May 19, 2012

3 Description of anomalies

3.1 ESR-27

The transition to ESR mode was triggered on May 3, 2012 (DOY 124) at 22:25 UT by the CSPAAD (Coarse Sun Pointing Attitude Anomaly Detector, it triggers for a 25-degree Sun off-pointing).
The last telemetry packets acquired before ESR-27 were examined and showed that the spacecraft performances and pointing were nominal There was no other anomaly.
Just before the anomaly, as reported in the "frozen packets", the Reaction wheels speeds were: -623 / -552 / 1499 rpm (flight values close to ground predictions for that day: -616 / -549 / 1493 rpm).
ESR was triggered by a false alarm raised by CSPAAD.

3.2 ESR-28 and Warm Start-Up

More than 4 days after the ESR-27 recovery (i.e. since transition into CRP), on May 8, 2012 (DOY 129) at 20:33UT another ESR was triggered by CSPAAD.

Just before ESR-28, as checked in TM, the Reaction wheels speeds were normal. Therefore ESR was triggered again by a false alarm raised by CSPAAD.

This time there was another anomaly: a **warm start-up** had occurred, which means the CDMU and all RTUs had been reconfigured to redundant side (in case of ESR, only A-RTU and S-RTU are reconfigured by COBS ESR monitoring function; this time the CDMU and P-RTU were also swapped to B-side).

The warm start-up was triggered with a “Normal Power Up” triggered by “OBDH bus error after retry (XIO)” (anomaly ID 4hex) for a memory load command sent to the SSR. The probable cause indicated by “COBS User Manual page 414” is: RTU not connected or not operable”.

Since the only commanding to the SSR at that time was done by the “intermittent recording mode”, the Warm startup was caused by being in “intermittent recording mode” when ESR triggered.
Practically the “intermittent recording patch” (in COBS) sent the SSR start record command while the PRCG sequence was executed to reconfigure the SVM RTU (as part of ESR monitoring actions) which induced a double OBDH error and a warm start-up. As a consequence the remaining part of the ESR monitoring actions were not executed and the LV-B was left powered (it was switched OFF later on).

The frozen packets acquired before the warm startup were examined and showed that PLM RTU-A +05V (D+05PRTA) was at 0.0399V (in svmhk3_1) whereas its daily average value is 0.05V. However a replay of old TM values showed that such a low value has been observed in the past without consequence (even at 0.02V when there is little PLM activity).

3.3 ESR-29 Triggering

After ESR-28 recovery, with spacecraft back in CRP, on May 9, 2012 (DOY 130) at 14:52UT another ESR was triggered by CSPAAD (which was already detected).

Just before ESR-29, as checked in TM, the Reaction wheels speeds were normal. Therefore ESR was triggered again by a false alarm raised by CSPAAD.

This time there was NO other anomaly.

4 Sequence of events

Time (UT)	Activities
	3-May (DOY 124)
22:25:28	**CSPAAD triggered ESR-27** (during a TM gap)
	4-May (DOY125)
04:15	***Started Contingency Script -06B ESR Initial operations***
04:52	*ESR Main*
05:25	***Switch to Contingency Script -18 script: ground based roll control*** Roll rate determination.
06:00	**UVCS** SH circ 64 switched ON at 60%
06:19	***Contingency Script -06AESR Recovery***
16:00	ACU-A ON
16:30	CAE-A ON
17:40	Reaction wheels switched ON and spun-up
18:48	**Spacecraft in CRP mode, wheel 2 at -3767 rpm**
	7-May (DOY 128)
	SSU Mapping performed but no solution for roll angle
15:13	**UVCS** substitution heater switched OFF
17:22	Roll maneuvers : +10°; later on -36°
	8-May (DOY 129)
	SSU Mapping performed again FDF: roll attitude -96.9 degrees No momentum management is needed before the roll maneuvers
12:10	Roll maneuver : -57.32° Wheels speeds: 1790 / -565 / -1919 rpm. Roll angle = 180°
14:10	In RMW
20:33	**CSPAAD triggered ESR-28**
20:34:49	**Warm Start-Up triggered due to OBDH errors**
21:40	***Started Contingency Script -06B ESR Initial operations***
23:16	*ESR Main (no need to fire thruster to reduce roll rate)*
	9-May (DOY 130)
02:37	***Started contingency CS-19***
03:35	***Contingency Script -06AESR Recovery***
05:11	ACU-A ON
05:33	CAE-A ON
06:50	Reaction wheels switched ON and spun-up
07:13	**Spacecraft in CRP mode, wheels at 1805 / -3565 / 1805 rpm**
	Contingency Script -07A Warm Start-Up Recovery
09:40	Start X_warm_rc to put CDMU and RTUs back on A side

10:05	Coms backup recovery
13:05	COBS Gyroless upload (K_gl_upld)
13:10	SSU Mapping: Roll at +175.761°
	Roll of +4.2° to reach +180°
14:52	**CSPAAD enabled and triggered: ESR-29**
14:55	***Started Contingency Script -06B ESR Initial operations***
15:11	*ESR Main (no need to fire thruster to reduce roll rate)*
16:50	***Contingency Script -06AESR Recovery***
17:16	ACU-A ON
17:46	CAE-A ON
19:26	Reaction wheels switched ON and spun-up
20:37	**Spacecraft in CRP mode, wheels at 1650 / -3530 / 1584 rpm**
	SSU Mapping FDF: roll attitude 43.23 degrees
	10-May (DOY 131)
01:26	**UVCS** SH circ 64 switched ON at 60%
15:57	**UVCS** SH circ 64 reduced from 60% to 40%
18:20	**Station Keeping (SK-78 first part) delta-V -0.3 m/s**
19:06	Wheels speeds 1705 / -3693 / 1606 rpm
19:15	**Station Keeping (SK-78 2nd part, aborted) delta-V -0.2 m/s**
19:35	RW2 speed decreasing from -3693 to -3900rpm (getting close to the high limit). SK aborted. Final wheels speeds 1809 / -3913 / 1637 rpm
20:20	MM Thruster 4A; Wheels speeds set at 2636 / -3783 / 677 rpm
20:55	MM Thruster 2A; Wheels speeds set at 1270 / -1050 / -599 rpm
22:45	**Station Keeping (SK-78 third part) delta-V -0.1525 m/s**
23:10	Wheels speeds 1364 / -1237 / -558 rpm
23:35	MM Thruster 5A; Wheels speeds set at 1680 / -1249 / -242 rpm
23:55	MM Thruster 2A; Wheels speeds set at 1586 / -1061 / -330 rpm
	11-May (DOY 132)
00:10	MM Thruster 3A; Wheels speeds set at 1566 / -1066 / -306 rpm
01:28	Upload SSU Patch 2A
21:35	**Spacecraft in Normal mode**
22:28	RSL enabled
	Continued with usual activities after maneuver and Instrument recovery after ESR
	15-May (DOY 136)
12:54	**UVCS** SH circ 64 switched OFF
	30-May (DOY 151)
11:03	Wheels speeds -924/ -494 / 1456 rpm
11:05	**Station Keeping (SK-79) delta-V -0.33 m/s**
11:56	Wheels speeds -703 / -1031 / 1629 rpm

5 ESR Recovery

5.1 After ESR-27

5.1.1 In ESR

During ESR-27, PROS temperatures were pretty stable with a slow decrease for equipment (LV and PT, especially for PT-A that cooled down to 9.4°C until CAE-A was switched ON).

Before the reactions wheels were switched ON, WDE (wheels electronics box) was at -13.7°C (design limit at -20C when not operating), same temperature was observed during the previous ESRs (ESR25 and ESR26).

During this ESR and for the second time, the wheels thermal circuits stayed in mode 2 (i.e. heaters always ON according to a duty cycle).
As a consequence:

- after their spin-up, the wheels warmed up:
    - RW2 (spun-up to 3600 rpm) to almost 35C
    - RW1 and RW3 (spun-up to 1800 rpm) to 25C

Note that the yellow limits (equal to design Operating limits) for the wheels external temperatures are: 0C to 60C. Therefore even with the thermal excursion observed during the ESR recovery, the wheels are well within their operating range.

5.1.2 ESR recovery

After several roll rate adjustments (using the reaction wheels), the spacecraft was put into CRP at 18:48 UT on May 4 (so 20 hours and 23 minutes after ESR-27 triggered).

Following entry into CRP, wheel 2 was spinning at about 3770rpm and stayed so during the following week-end. This is acceptable since:

- RW speed high limits are yellow at 3900rpm and red at 4000rpm
- RW temperatures are well below the high limit of 60°C.

With SSU mapping data the attitude team was not able to converge on one solution for the roll angle. The spacecraft was left in CRP over the week-end.
On Monday there was still a problem to get a roll angle form the SSU mapping.

However by looking at the stars motion across the SSU field of view (see in Annex), one could deduct the roll angle to be close to either +90 or -90 degrees.

On Tuesday May 8, several roll profiles were performed (first ones to provide different mapping data). Finally, taking into account the spacecraft halo orbit ephemeris, the roll angle was measured as being -97 degrees and spacecraft rolled to its target position of +180 degrees.

5.2 After ESR-28 and Warm start-up

5.2.1 ESR recovery

When ESR triggered, the total momentum of the wheels was still almost null on the x-axis, therefore no roll adjustment (neither for ground based roll control nor the rate adjustments before getting into CRP).
So spacecraft was back in CRP at 7:13 on May 9 (10 hours and 39 minutes after ESR triggered).

5.2.2 Warm start-up recovery

With concurrent ESR and warm start-up, the ESR recovery has priority. Therefore the ESR was recovered first and then, when in CRP, the data handling was successfully reconfigured back to nominal side. See timeline of events above.

5.3 UVCS substitution heater

See table of events and UVCS temperatures in Annex A2.

After ESR-27 (the first of this series), UVCS had received the ESR warning flag and was in the “Bogart safe conditions” (UVCS internal heaters turned ON and UVCS low voltage kept ON). However a contingency script had still the command to switch ON UVCS substitution heater at 60% (performed on May 4 at 06:00).

UVCS was then getting too hot: QTUI1A reached 36°C on May 7 (Yellow High limit set at 40°C). Therefore the instrument team requested to switch OFF its substitution heater (which was done by the FOT on May 7 at 15:13).

After ESR-28 and warm start-up, observing decreasing temperatures, the instrument team thought UVCS was in the “old safe” configuration. In such a case, UVCS was getting too cold and UVCS sensor temperature violated the Yellow Low limit (QTUI1A at 4.79°C on May 10; YLL=5°C). UVCS substitution heater was switched ON (circuit 84 at 60%) (on May 10 at 01:26).

However it turned out that UVCS internal heaters were still ON and circuit 64 was reduced to 40% (May 10 at 15:57) to avoid over-heating the instrument. With this 40% setting, UVCS temperatures stabilized (QTUI1A at 19°C).

Finally on May 15 at 12:54, UVCS circ 64 was switched OFF and the instrument was back to its normal thermal configuration.

5.4 After ESR-29

5.4.1 ESR recovery

Same remark as after ESR-28 for wheels momentum.
Spacecraft was back in CRP at 20:37 on May 9 (less than 6 hours after ESR triggered). With a roll angle measured at 43 degrees, a roll to +180° would have put one wheel at a low speed. Decision was taken to perform first the station keeping burns, all the more as correcting the orbit was crucial, and then to roll back to +180°

5.5 Station keeping maneuver (SK-78)

FDF reported that during the 20.3 hours in ESR (for ESR-27), the orbit has been disturbed by a total delta-V: 0.5 m/s

In order to correct the effect on the orbit of the ESR thruster firings, 3 segments of Station Keeping were executed on May 10 2012 (the third one was actually performed after the first two Momentum management burns (see sequence of events above).

SK-78 first part **2012-May-10**

Start time (UTC)	Delta-V (m/s)	Fuel used (kg)	Duration (min)
2012.131.18:20	-0.3	0.32	45.0

Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)
1	134	975.889	130.769	20
2	134	1003.455	134.463	20
4	67	77.737	5.208	40
6	67	88.196	5.909	40

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial	1632	-3525	1632
Final	1705	-3693	1606
Delta (Final – Initial)	73	-168	-26

The drift in RW speeds started at about mid-course of the burn, when the firing thrusters were warm.

SK-78 second part (as aborted at 2/3) **2012-May-10**

Start time (UTC)	Delta-V (m/s)	Fuel used (kg)	Duration (min)
2012.131.19:15	-0.13	0.14	20.0

Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)
1	60	969.204	58.152	20
2	60	996.58	59.795	20
4	30	77.225	2.317	40
6	30	87.592	2.628	40

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial	1705	-3693	1606
Final	1809	-3913	1637
Delta (Final – Initial)	104	-220	31

For the second SK segment, the drift in RW speeds started at the very beginning of the burn (the thrusters were warmer than for the first segment due to the soak back effect). As a consequence the burn was aborted to avoid having RW2 too close to the high limit of 4000rpm (so above values are as aborted at 2/3 of commanded burn).

A third segment of SK-78 was performed later on the same day:

SK-78 third part **2012-May-10**

Start time (UTC)	Delta-V (m/s)	Fuel used (kg)	Duration (min)
2012.131.22:45	-0.1525	0.16	23.0

Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)
1	68	978.327	66.526	20
2	68	1005.956	68.405	20
4	34	77.975	2.651	40
6	34	88.417	3.006	40

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial	1269	-1052	-599
Final	1364	-1237	-558
Delta (Final – Initial)	95	-185	41

5.6 Momentum Management (May-10 2012)

First a 2-segment Momentum Management (MM) was performed after the first 2 segments of Station Keeping.

Momentum Management first segment **2012-May-10**

Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration (min)
2012.131.20:20	4A (Y)	40	217.3	8.692	35	23.3

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Observed Initial	1810	-3913	1638
Observed Final	2636	-3783	677
Observed Delta (Final – Initial)	826	130	-961
Expected Delta (Final – Initial)	829	130	-959

Momentum Management second segment **2012-May-10**

Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration (min)
2012.131.20:55	2A (P)	68	98.2	6.678	60	68.0

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Observed Initial	705	855	-1055
Observed Final			
Observed Delta (Final – Initial)	-705	-855	1055
Expected Delta (Final – Initial)	-1373	2726	-1284

Then, after the third segment of SK, 3 other MM burns were executed:

Momentum Management third segment **2012-May-10**

Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration (min)
2012.131.23:35	5A (R)	14	102.6	1.437	35	8.2

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Observed Initial	1364	-1237	-558
Observed Final	1680	-1249	-242
Observed Delta (Final – Initial)	316	-12	316
Expected Delta (Final – Initial)	319	-12	319

Momentum Management fourth segment **2012-May-10**

Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration (min)
2012.131.23:55	2A (P)	5	97.7	0.489	60	5.0

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Observed Initial	1680	-1249	-242
Observed Final	1586	-1061	-330
Observed Delta (Final – Initial)	-94	188	-88
Expected Delta (Final – Initial)	-93	185	-87

Momentum Management fifth segment **2012-May-11**

Start time (UTC)	Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)	Duration (min)
2012.132.00:10	3A (Y)	2	129.7	0.259	35	1.2

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Observed Initial	1586	-1061	-330
Observed Final	1566	-1066	-306
Observed Delta (Final – Initial)	-20	-5	24
Expected Delta (Final – Initial)	-21	-6	26

5.7 Nominal roll attitude recovery

The spacecraft was rolled back to its normal “inverted” position (180 degrees).

5.8 Back to Normal Mode

SOHO was back in Normal Mode on May 11 at 21:35.

5.9 Station keeping maneuver (SK-79)

An additional station keeping was needed to correct for the effect of ESR thruster firings on the orbit.
This station keeping was successfully performed on May 30 and induced an excursion of RW2 speed of -537 rpm.

SK-79 **2012-May-30**

Start time (UTC)	Delta-V (m/s)	Fuel used (kg)	Duration (min)
2012.151.11:05	-0.3337	0.362	50.0

Thruster	Pulses	Pulse length (ms)	On time (s)	Interval (s)
1	151	971.382	146.679	20
2	151	999.502	150.925	20
4	76	76.97	5.850	40
6	76	87.269	6.632	40

Wheel speeds (rpm)	Wheel 1	Wheel 2	Wheel 3
Initial	-924	-494	1456
Final	-703	-1031	1629
Delta (Final – Initial)	221	-537	173

5.10 FPSS and SAS1 comparison

Using ESR recoveries data, a comparison of FPSS-A and SAS1 (both A and B) data has been performed and showed good performances of these 3 sun sensors.
For details see RD4.

6 Conclusion

The ESR 27, 28 and 29 were triggered on a CSPAAD false detection.

For obvious reasons, CSPAAD has been declared faulty and has been disabled (not used any more to trigger an ESR). A study is on-going to prepare a “CSPAAD replacement” off-pointing monitoring, based on SAS1-B outputs.

The ESR recovery was performed successfully.

The cause of the warm start-up was likely a side effect of the “intermittent recording” mode when ARO sequence is executed.

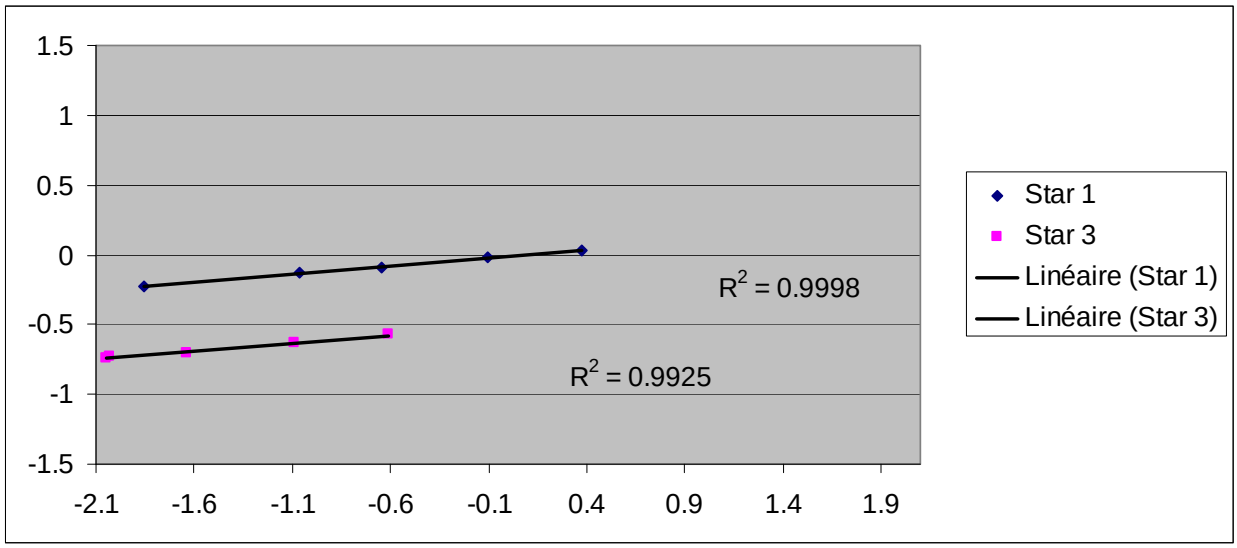
Fuel consumption of ESR:

- B-thrusters firings during the 36 hours in ESR: estimated between 0.5 and 1 kg
- MM on May 10: 0.02 kg
- SK-78 (3 segments) on May 10: 0.63 kg (estimated)
- SK-79 on May 30: 0.36 kg

Total: estimated between 1.5 and 2kgs.

7 Annex A1: stars motion in SSU field of view

The plot below shows the motion of tracked stars in the SSU field of view between May 4 23:20 and May 7 7:09. Note that star 3 got stuck at the border of the field of view.



8 Annex A2: UVCS temperatures

Date	DOY	Time (UT)	Event	QT05	QTUR1	QTUI1A
2012 May 3	124	16:25	before ESR-27	16	21.9	10.8
2012 May 4	125	5:55	in ESR	15.7	21.2	14.6
2012 May 4	125	6:00	UVCS sub heater circ 64 switched ON at 60%			
2012 May 5	126	13:15	UVCS warmed up by sub heater	16.7	23	**35.3**
2012 May 6	127	21:28	UVCS temperatures reached a plateau	16.7	23.4	**36**
2012 May 7	128	15:13	UVCS sub heater circ 64 switched OFF	16.7	23.4	**36**
2012 May 8	129	20:30	before ESR-28 and Warm satrt-up; UVCS had cooled down	16	21.9	15.7
2012 May 8	129	20:33	ESR-28 and warm start-up			
2012 May 9	130	20:30	UVCS much cooler	15.7	21.6	**5.4**
2012 May 10	131	1:20		15.7	21.2	**4.8**
2012 May 10	131	1:26	UVCS sub heater circ 64 switched ON at 60%			
2012 May 10	131	15:55		16	21.9	21.9
2012 May 10	131	15:57	UVCS sub heater circ 64 reduced to 40%			
2012 May 15	136	12:50		16	22.3	19.3
2012 May 15	136	12:54	UVCS sub heater circ 64 switched OFF			
2012 May 16	137	13:54	UVCS back to normal thermal situation	15.7	21.6	10.2

Distribution list

GSFC	H. BENEFIELD E.SOTER L. JOHNSON T.v. OVERBEEK	D. QUINN J. GURMAN N. PISTON	B. FLECK P. CROUSE G. DIXON Jr
ESTEC	J. ELLWOOD	P. RUMLER	F. TESTON
		P. POINAS	P. STRADA
EADS ASTRIUM Toulouse	JP. OLIVE M. JANVIER	D. LEBRETON P. TEMPORELLI	P. AYACHE

Contacts:

JP. OLIVE — tel: 33 5 62 19 60 42
e-mail: jean-philippe.olive@astrium.eads.net

T. VAN OVERBEEK — tel: 1 301 286 5963
e-mail: tvoverbeek@hst.nasa.gov