ROSETTA RPC-LAP
OPERATIONS REPORT
LUTETIA FLYBY

Operations on July 7 - 13, 2010

IRFU-ROS-OPR-LUT
Version 1.4
28 Aug 2012

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Contents

Document history

Revision	Date	Comment
0.1	2010-07-09	Initiated
1.0	2010-09-06	First release, post-flyby data remains to analyze.
1.1	2011-12-02	Updated with post-flyby data.
1.2	2012-04-25	Corrections after archive review: Missing figure inserted, figure numbers corrected, minor editorial changes.
1.3	2012-05-03	Sections 4.1 and 5 revised with discussion of remaining offset on probe 2.
1.4	2012-08-28	Corrections after review by ESA/PSA.

1 Introduction

This is the report from the operations of RPC-LAP during the Rosetta flyby of asteroid 21 Lutetia, with closest approach close to 15:54 UT in July 10.

Goals of LAP operations during this flyby:

- Observe the solar wind and look for any signatures that may relate to asteroid-solar wind interaction.
- Determine photoemission at this unprecedentedly large heliocentric distance
- Compare current-voltage characteristics obtained by voltage and current bias sweeps.

All operations were succesful.

2 Orbit and pointing

Figure 1 shows the position of Rosetta in the planetary system at the time of the operation. The heliocentric distance at the time of Rosetta closest approach to the asteroid was 2.72 AU. The spacecraft attitude profile is shown in Figure 2.

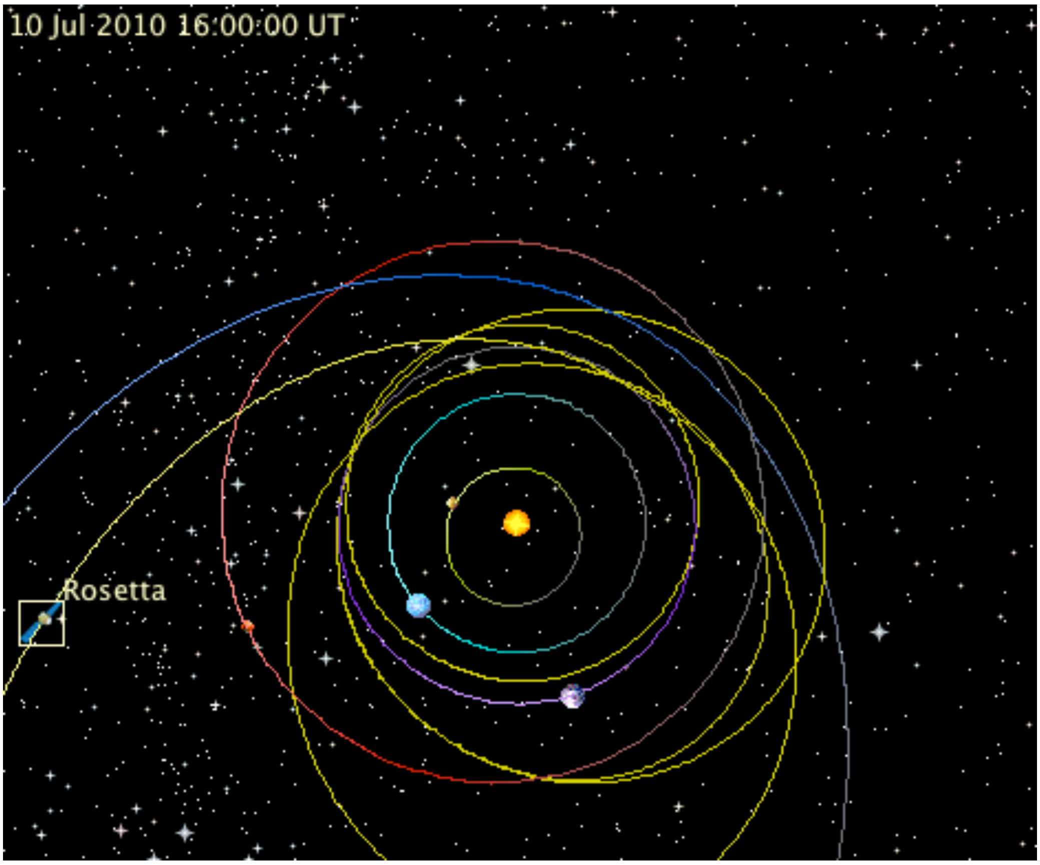

Figure 1. Rosetta position in the planetary system at the Lutetia flyby. Produced by orbit tool at http://rosetta.esa.int.

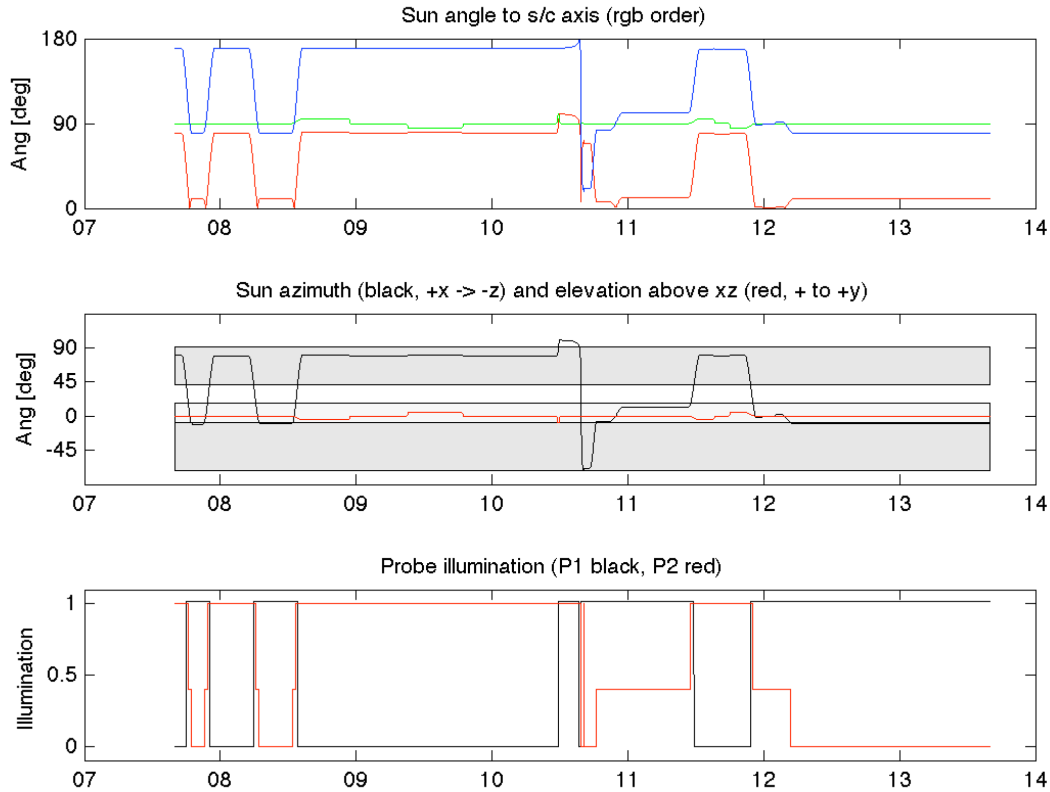

Figure 2. Pointing profile for the Lutetia flyby.
Top: Angles to the sun for the s/c axes.
Centre: The solar aspect angle is shown in black. The red curve is the solar elevation above the xz plane. The shaded regions indicate the illumination of the LAP probes when the black lines enter these regions. The upper shaded region indicates when LAP probe 1 is in eclipse behind the solar panels. The lower two shaded areas show when LAP probe 2 is eclipsed by the spacecraft body (lower, darker shading) or possiby eclipsed by the high gain antenna (upper, lighter shading).
Bottom: Probe 1 (black) and 2 (red) illumination. 0 = eclipse by solar panels (P1) or s/c (P2); 0.4 = possible eclipse by HGA (P2 only), 1 = sunlight.

From the attitude profile illustrated in Figure 2, an illumination prediction as shown in Table 1 can be derived for the LAP probes.

Figure 3 compares the actual Lutetia flyby to the rehearsal in March 14-15, 2010, with simulated closest approach at midnight. From CA-4 hrs to CA+1 hr, the pointing profiles are very similar.

```
P1 initially behind s/c
P2 initially in sunlight

P1 in sunlight from 2010-07-07 17:59:00  0 01:59
P2 behind HGA from  2010-07-07 18:19:00  0 02:19
P2 behind s/c from  2010-07-07 18:49:00  0 02:49
P2 behind HGA from  2010-07-07 21:11:00  0 05:11
P2 in sunlight from 2010-07-07 21:43:00  0 05:43
P1 behind s/c from  2010-07-07 22:05:00  0 06:05
P1 in sunlight from 2010-07-08 05:54:00  0 13:54
P2 behind HGA from  2010-07-08 06:16:00  0 14:16
P2 behind s/c from  2010-07-08 06:49:00  0 14:49
P2 behind HGA from  2010-07-08 12:49:00  0 20:49
P2 in sunlight from 2010-07-08 13:19:00  0 21:19
P1 behind s/c from  2010-07-08 13:39:00  0 21:39
P1 in sunlight from 2010-07-10 11:45:00  2 19:45
P1 behind s/c from  2010-07-10 15:24:00  2 23:24
P1 in sunlight from 2010-07-10 15:42:00  2 23:42
P2 behind HGA from  2010-07-10 15:44:00  2 23:44
P2 behind s/c from  2010-07-10 15:46:00  2 23:46
P2 in sunlight from 2010-07-10 16:15:00  3 00:15
P2 behind s/c from  2010-07-10 16:16:00  3 00:16
P2 behind HGA from  2010-07-10 18:24:00  3 02:24
P2 in sunlight from 2010-07-11 11:06:00  3 19:06
P1 behind s/c from  2010-07-11 11:39:00  3 19:39
P1 in sunlight from 2010-07-11 21:40:00  4 05:40
P2 behind HGA from  2010-07-11 22:05:00  4 06:05
P2 behind s/c from  2010-07-12 04:43:00  4 12:43
```

Table 1. Predicted LAP illumination conditions for the Lutetia flyby. P1 shadowing is actually caused by the solar panels, not by the s/c body. The two rightmost columns give time relative to RPC turn-on at the start of operations in days and HH:MM.

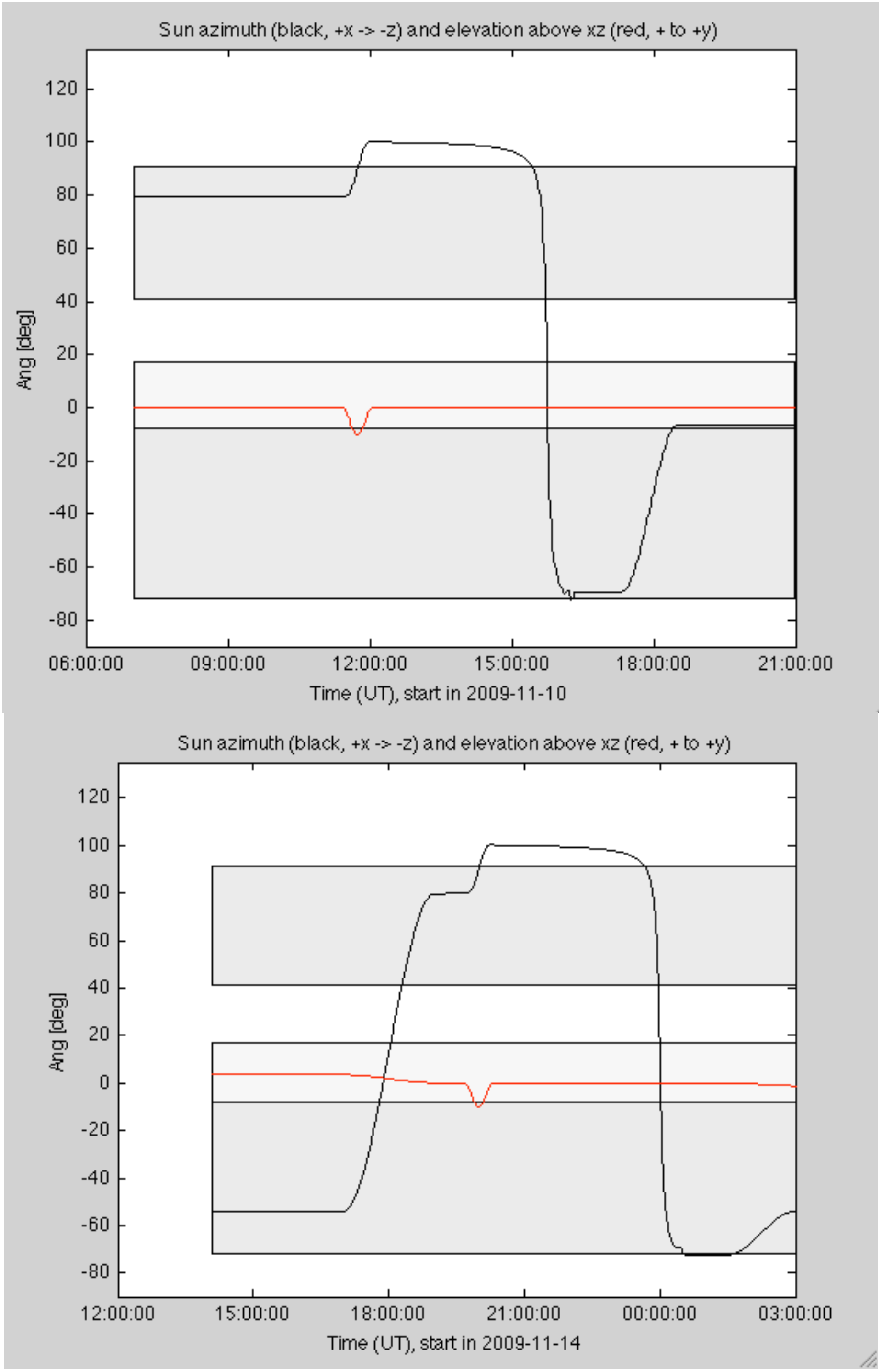

Figure 3. Pointing profile for the Lutetia flyby (top) and rehearsal (bottom). From CA-4 hrs to CA+1 hr, the pointing profiles are very similar. Date labels are wrong: the top is for July 10, 2010, the lower for March 14-15, 2010. The solar aspect angle is shown in black. The red curve is the solar elevation above the xz plane. The shaded regions indicate the illumination of the LAP probes when the black lines enter these regions. The upper shaded region indicates when LAP probe 1 is in eclipse behind the solar panels. The lower two shaded areas show when LAP probe 2 is eclipsed by the spacecraft body (lower, darker shading) or possiby eclipsed by the high gain antenna (upper, lighter shading).

3 Operations

3.1 Overview

The LAP operations can be divided into the following blocks:

A. Turn on LAP in normal TM mode (NM) 3 days before c/a (100707 16:10-23:10), running bias sweeps on both probes (NM NN). Keep this mode for 7 hrs, as there are two large attitude sweeps in this time frame, to gather data on pointing effects this far from the sun.
B. Internal offset determination for 20 minutes (100707 23:10-23:30, also in block I).
C. Normal TM mode (NM) operations in EE mode (NM EE), for 2 1/2 days when approaching the asteroid. Standard science operation for monitoring solar wind, with bias adjustments as appropriate from probe illumination conditions predicted from the attitude profile (100707 23:30 - 100710 12:54, also in block F)
D. Burst TM mode (BM) operations in EE mode (BM EE), from CA-3 hrs to CA+1 hr (100710 12:54 - 16:50). Standard science operation for monitoring solar wind and well suited for searching for any signatures of asteroid-solar wind interaction, with bias adjustments as appropriate from probe illumination conditions predicted from the attitude profile.
E. BM operations in E- mode, with probe 2 handed over to MIP for LDL operations, from CA+1 hr to CA+3hrs (100710 16:50 - 18:54). Standard science operation for monitoring solar wind as long as P1 is illuminated.
F. Normal TM mode (NM) operations in EE mode (NM EE) when RPC goes back to NM. Standard science operation for monitoring solar wind, with bias adjustments as appropriate from probe illumination conditions predicted from the attitude profile (100710 18:54 - 100712 05:21, also in block C).
G. Bias current stepping on P1 to provide a current-voltage curve from this mode, which we have never done before in space. A number of manually commanded bias settings at 60 second intervals give an artificial probe sweep. Signatures of these steps in P2 data are also of interest. (100712 05:21 - 05:40).
H. Bias voltage sweeps on both probes (NM NN), for comparison to step G data. 100712 05:40 - 06:30).
I. Internal offset determination for 20 minutes (100712 06:30 - 06:55, also in block B).
J. Operations in "quiet LDL mode" (NM N-), meaning that LAP hands over probe 2 to MIP for LDL operations and puts probe 2 into bias voltage mode (N-). This is not as scientifically useful for LAP, but gives MIP optimal data opportunity, for 33 hrs until end of operations (100712 06:55 - 100713 16:00)

3.2 Operational details

Table 2 below summarizes the RPC operations planning, including other RPC instruments. The timeline for the other instruments does not necessarily reflect the actual outcome: e.g., ICA was turned off during the operation. **For LAP, all operations went smoothly, and all data are nominal**.

The table is copied from the RPC operations planning wiki pages, with the columns at extreme left and right added to identify the operational block in Section 3.1 and to comment on the outcome of the operations, respectively. The reference time is the LAP startup time, 2010-07-07 16:00:00 UT. Time in UT has been added to the table for most LAP-relevant steps (2nd line of a time entry, in format DD_HH:MM:SS or , if SS=00, DD_HH:MM, where DD is the date in July 2010).

The time given for the bias settings are for the first command in the bias setting command sequence. The actual command for setting the bias current is sent 3 seconds later.

Block	Step	Time	Status	Sequence	Comment	Post-operational notes
	010				Status before this step: RPC ON; all instruments OFF Sequence execution time: RP_START (COUNT=090100) = (07-Jul-2010) 188_16:00:00	
	030	+000_00:10:00	on	ARPS811A # MAG Mode Change --- VSK01264 = SID2 [ENG] # ModeMAG	MAG ON in normal mode.	

A	040	+000_00:10:01
		07_16:10:01
			on	ARPS809A # LAP Mode Change
				--- 	
				VSK01262 = SID2 [ENG] # ModeLAP
				VSK01267 = 0x50 # LAParam
				VSK01269 = 0x0005 # LAP EEPROM Boot Bank
					LAP ON in normal mode, running macro 600 (sweep).
					
					We keep this mode for the first 7 hrs as there are two large attitude sweeps in this period. This will give good attitude characteristics at this large heliocentric distance (2.72 AU).	

	050	+000_00:10:02	on	ARPS810A # MIP Mode Control
				--- 	
				VSK01263 = SID2 [ENG] # ModeMIP
				VSK01268 = 0xff # MIPParam
					MIP ON in normal mode.	

B	060	+000_07:10:00
		07_23:10
			on	ARPS809A # LAP Mode Change
				--- 	
				VSK01262 = SID2 [ENG] # ModeLAP
				VSK01267 = 0x04 # LAParam
				VSK01269 = 0x0005 # LAP EEPROM Boot Bank
					LAP offset determination (macro 0x104)
					
					The attitude stabilizes at 23:00 (000_07:00), so this is a good point to stop sweep operations.	

C	070	+000_07:30:00 07_23:30	on	ARPS809A # LAP Mode Change ---	LAP to NM EE mode (macro 0x503) Ibias -8/+3 nA	

				VSK01262 = SID2 [ENG] # ModeLAP
				VSK01267 = 0x43 # LAParam
				VSK01269 = 0x0005 # LAP EEPROM Boot Bank
					P1 is in eclipse and P2 sunlit, so we expect P1 saturation until next bias setting.	

	072	+000_07:35:00
		07_23:35
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E7D # E_Fix_Bias_param_2
					LAP bias P1 +1 nA, P2 -5 nA (P1 eclipse, P2 sunlit)
					
					This sets nominal bias for this illumination.	

	090				+000_13:00:00 = (08-Jul-2010) 189_05:00:00 -> Start slew to RPC pointing- 70 deg < SAA < 90 deg +000_15:00:00 = (08-Jul-2010) 189_07:00:00 -> End slew +000_20:40:00 = (08-Jul-2010) 189_12:40:00 -> End of RPC pointing; slew to SAA 169 deg	

	092	000_13:55:00
		08_05:55
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E8E # E_Fix_Bias_param_2
					LAP bias P1 and P2 -5 nA
					Both probes sunlit from 05:54	

	094	000_14:16:00
		08_06:16
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7D8E # E_Fix_Bias_param_2
					LAP bias P1 -5 nA, P2 +1 nA
					P2 into HGA eclipse 06:16, s/c eclipse 06:49.	

	096	000_21:19:00
		08_ 13:19
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E8E # E_Fix_Bias_param_2
					LAP bias P1 and P2 -5 nA
					P2 out of s/c eclipse 12:49, out of HGA eclipse 13:19.	

	098	000_21:38:00
		08_13:38
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E7D #
					LAP bias P1 +1 nA and P2 -5 nA
					P1 into eclipse at 13:39.	

				E_Fix_Bias_param_2		
	100				WOL+TCM1 Start +001_07:00:00 = (08-Jul-2010) 189_23:00:00	
	110				WOL+TCM1 End = **BREA1** . +001_11:00:00 = (09-Jul-2010) 190_03:00:00 In case of safe mode before BREA1, execution of this sequence (RP01) will be terminated here and sequence RP01BR will be run instead.	
	190				Two options here: 1) If S/C is operating on 4 wheels: TCM2 will be executing according to plan and it will take 3h 2) if S/C is operating on 3 wheels: the TCM2 will **not** be executed; TCM2 will become an emergency TCM; if TCM is executed it will take 5h; if TCM is executed payload will be switched off before execution and payload will be turned back on according to BREA2.	
	200				TCM2 Start (only if S/C is on 4 wheels) +002_11:00:00 = (10-Jul-2010) 191_03:00:00	
	210				TCM2 End (only if S/C is on 4 wheels) +002_14:00:00 = (10-Jul-2010) 191_06:00:00	

	220	+002_14:30:00	on	ARPS807A # IES Mode Control
				--- 	
				VSK01260 = SID2_HV_ON [ENG] # ModeIES
				VSK01265 = 0xff # IESParam
					IES ON in Normal mode 30min after completion of second TCM (Absolute Time = July 10, DOY 191, 06:30:00)	

	230	+002_14:30:01	on	ARPS808A # ICA Mode Control
				--- 	
				VSK01261 = SID2_HV_ON [ENG] # ModeICA
				VSK01266 = 0x0A # ICAParam
					ICA ON in Normal mode 30min after completion of second TCM	

	240	+002_14:40:00	on	ARPS140A # IES Sci Conf and Acq --- VRPD1121 = 0x05 # IES-	IES Table #5 Normal Mode (Absolute Time = July 10, DOY 191, 06:40:00)	

				DATA-ACQ-TABLE TabNo VRPD1011 = 0x01 [RAW] # IES-COMM-RATE-MODE Rate		
	300				+002_19:00:00 = (10-Jul-2010) 191_11:00:00 = **BREA2** . In case of safe mode before BREA2 and after BREA1, execution of this sequence (RP01) will be terminated here and sequence RP01BR2 will be run instead.	

	350	002_19:46:00
		10_11:46
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E8E # E_Fix_Bias_param_2
					LAP bias P1 and P2 -5 nA Both probes sunlit from 11:45.	

	420				**CA - 2h50min53s (circa 3h)** . +002_20:54:00 = (10-Jul-2010) 191_12:54:00 -> RPC to BURST mode	
	430	+002_20:54:00	on	ARPS811A # MAG Mode Change --- VSK01264 = SID3 [ENG] # ModeMAG	MAG to Burst mode	

D	440	+002_20:54:01
		10_12:54:01
			on	ARPS809A # LAP Mode Change
				--- 	
				VSK01262 = SID3 [ENG] # ModeLAP
				VSK01267 = 0x44 # LAParam
				VSK01269 = 0x0005 # LAP EEPROM Boot Bank
					LAP to burst mode, macro 504 (EE), bias (-8,+3) nA (bias adjust follows in step 485).	

	450	+002_20:54:02	on	ARPS810A # MIP Mode Control
				--- 	
				VSK01263 = SID3 [ENG] # ModeMIP
				VSK01268 = 0xff # MIPParam
					MIP to Burst mode	

	460	+002_20:54:03	on	ARPS140A # IES Sci Conf and Acq
				--- 	
				VRPD1121 = 0x00 # IES-DATA-ACQ-TABLE TabNo
				VRPD1011 = 0x02 [RAW] # IES-COMM-RATE-MODE Rate
					IES Table #0 Burst Mode (Absolute Time = July 10, DOY 191, 12:54:03)	

	470	+002_20:54:05	on	ARPS808A # ICA Mode	ICA to Burst mode	

				Control
				--- 	
				VSK01261 = SID3_HV_ON [ENG] # ModeICA
				VSK01266 = 0x1A # ICAParam		

	475	+002_21:00:00
		10_13:00
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E8E # E_Fix_Bias_param_2
					LAP bias P1 and P2 -5 nA
					Both probes sunlit since 11:45.	

	480	+002_23:24:00
		10_15:24
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E7D # E_Fix_Bias_param_2
					LAP bias P1 +1 nA, P2 -5 nA
					P1 enters eclipse 15:24.	

	485	+002_23:43:00
		10_15:43
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E8E # E_Fix_Bias_param_2
					LAP bias -5 nA on both probes
					P1 sunlit from 15:42. One extra minute added by experience from rehearsal.	

	490	+002_23:44:00
		10_15:44
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7D8E # E_Fix_Bias_param_2
					LAP bias P1 -5 nA , P2 +1 nA (P1 sun, P2 eclipse)
					P2 into HGA eclipse 15:44, s/c eclipse 15:46	

	500				**CLOSEST APPROACH** . +002_23:44:53 = (10-Jul-2010) 191_15:44:53	

E	550	003_00:50:00
		10_16:50:00
			on	ARPS809A # LAP Mode Change
				--- 	
				VSK01262 = SID3 [ENG] # ModeLAP
				VSK01267 = 0x64 # LAPParam
				VSK01269 = 0x0005 # LAP EEPROM Boot Bank
					LAP to LDL-enabled mode 0x704 (BM E-)
					Bias is too high for Lutetia (-29 nA) so we expect saturation at this point.	

	560	003_00:51:04	on	ARPS496A # Load MIP Cfg Table --- VRPG4001 = 0x2600 # Load_Config_detail_1	MIP to LDL (executes 2 AQPs after LAP LDL setting)	

				VRPG4002 = 0x0011 # Load_Config_detail_1
				VRPG4003 = 0x0207 # Load_Config_detail_1		

	570	003_00:52:08
		10_16:52:08
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x808E # E_Fix_Bias_param_2
					LAP bias P1 -5 nA for sunlight (P2 0 nA though now used by MIP)	

	580	003_01:54:00	on	ARPS496A # Load MIP Cfg Table
				--- 	
				VRPG4001 = 0x2600 # Load_Config_detail_1
				VRPG4002 = 0x0051 # Load_Config_detail_1
				VRPG4003 = 0x0207 # Load_Config_detail_1
					MIP in LDL transmitting level : divided y 2	

	600				**CA + 3h 9min 53s (circa 3h)** . +003_02:54:00 = (10-Jul-2010) 191_18:54:00 -> RPC back to NORMAL mode	
	610	+003_02:54:00	on	ARPS811A # MAG Mode Change --- VSK01264 = SID2 [ENG] # ModeMAG	MAG back to Normal mode	

F	620	+003_02:54:01
		10_18:54:01
			on	ARPS809A # LAP Mode Change
				--- 	
				VSK01262 = SID2 [ENG] # ModeLAP
				VSK01267 = 0x43 # LAParam
				VSK01269 = 0x0005 # LAP EEPROM Boot Bank
					LAP to normal mode, macro 503: EE, P1 bias -8 nA, P2 bias +3 nA.	

	630	+003_02:54:02	on	ARPS810A # MIP Mode Control
				--- 	
				VSK01263 = SID2 [ENG] # ModeMIP
				VSK01268 = 0xff # MIPParam
					MIP back to Normal mode	

	640	+003_02:58:00
		10_18:58:00
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7D8E # E_Fix_Bias_param_2
					LAP bias P1 -5 nA , P2 +1 nA (P1 sun, P2 eclipse) Bias setting following switch to normal mode.	

	650	+003_04:54:04	on	ARPS808A # ICA Mode Control --- VSK01261 =	ICA back to Normal mode	

				SID2_HV_ON [ENG] # ModeICA
				VSK01266 = 0x0A # ICAParam		

	660	+003_05:00:00	on	ARPS140A # IES Sci Conf and Acq
				--- 	
				VRPD1121 = 0x05 # IES-DATA-ACQ-TABLE TabNo
				VRPD1011 = 0x01 [RAW] # IES-COMM-RATE-MODE Rate
					IES Table #5 Normal Mode (Absolute Time = July 10, DOY 191, 21:00:00)	

	690	+003_09:45:00	on	ARPS808A # ICA Mode Control
				--- 	
				VSK01261 = HV_OFF [ENG] # ModeICA
				VSK01266 = 0xff # ICAParam
					ICA HV off 15 min before WOL start	

	695	+003_09:55:00	on	ARPS141A # Change IES Mode --- VRPD1431 = LVSCI [ENG]	IES to LVSCI mode 5 min before WOL (Absolute Time = July 11, DOY 192, 01:55:00)	
	700				WOL Start +003_10:00:00 = (11-Jul-2010) 192_02:00:00	
	710				WOL End +003_12:00:00 = (11-Jul-2010) 192_04:00:00	
	720	+003_12:05:00	on	ARPS141A # Change IES Mode --- VRPD1431 = HVSCI [ENG]	IES to HVSCI mode 5 min after WOL (Absolute Time = July 11, DOY 192, 04:05:00)	

	725	+003_12:10:00	on	ARPS808A # ICA Mode Control
				--- 	
				VSK01261 = HV_ON [ENG] # ModeICA
				VSK01266 = 0xff # ICAParam
					ICA HV back ON 10 min after WOL end	

	730	+003_12:15:00	on	ARPS140A # IES Sci Conf and Acq
				--- 	
				VRPD1121 = 0x05 # IES-DATA-ACQ-TABLE TabNo
				VRPD1011 = 0x01 [RAW] # IES-COMM-RATE-MODE Rate
					IES Table #5 Normal Mode (Absolute Time = July 11, DOY 192, 04:15:00)	

	740	+003_19:06:00
		11_11:06
			on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x8E8E #
					LAP bias -5 nA on both probes
					P2 sunlit from 11:06.	

				E_Fix_Bias_param_2		
	745	+003_19:39:00 11_11:39	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x8E7D # E_Fix_Bias_param_2	LAP bias P1 +1 nA, P2 -5 nA P1 into eclipse 11:39.	
	750	+004_05:40:00 11_21:40	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x8E8E # E_Fix_Bias_param_2	LAP bias -5 nA on both probes P1 sunlit from 21:40.	
	755	+004_06:05:00 11_22:05	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D8E # E_Fix_Bias_param_2	LAP bias P1 -5 nA, P2 +1 nA P2 into HGA eclipse 22:05, s/c eclipse 04:43	
G	761	+004_13:21:00 12_05:21	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D7D # E_Fix_Bias_param_2	LAP bias stepping P1: 7D = 3 = +1 nA First in a series of steps to verify bias current settings. Inserted after attitude stabilizes at 004_13:15 (2010-07-12 05:15).	
	762	+004_13:22:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D7E # E_Fix_Bias_param_2	LAP bias stepping P1: 7E = 2 = +0.7 nA	
	763	+004_13:23:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D7F # E_Fix_Bias_param_2	LAP bias stepping P1: 7F = 1 = +0.344 nA	
	764	+004_13:24:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 #	LAP bias stepping P1: 80 = 0 = 0 nA	

				IO_Poke_param_3 VRPD3050 = 0x7D80 # E_Fix_Bias_param_2		
	765	+004_13:25:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D81 # E_Fix_Bias_param_2	LAP bias stepping P1: 81 = -1 = -0.344 nA	
	766	+004_13:26:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D82 # E_Fix_Bias_param_2	LAP bias stepping P1: 82 = -2 = -0.7 nA	
	767	+004_13:27:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D84 # E_Fix_Bias_param_2	LAP bias stepping P1: 84 = -4 = -1.4 nA	
	768	+004_13:28:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D88 # E_Fix_Bias_param_2	LAP bias stepping P1: 88 = -8 = -2.8 nA	
	769	+004_13:29:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D8E # E_Fix_Bias_param_2	LAP bias stepping P1: 8E = -14 = -5 nA	
	770	+004_13:30:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D91 # E_Fix_Bias_param_2	LAP bias stepping P1: 91 = -17 = -6 nA	
	771	+004_13:31:00	on	ARPF390A # RPC LAP Set Bias --- VRPD3046 = 0x0000 #	LAP bias stepping P1: 94 = -20 = -7 nA	

				Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7D94 # E_Fix_Bias_param_2		

	772	+004_13:32:00	on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7D97 # E_Fix_Bias_param_2
					LAP bias stepping P1: 97 = -23 = -8 nA	

	773	+004_13:33:00	on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7D9A # E_Fix_Bias_param_2
					LAP bias stepping P1: 9A = -26 = -9 nA	

	774	+004_13:34:00	on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7D9D # E_Fix_Bias_param_2
					LAP bias stepping P1: 9D = -29 = -10 nA	

	775	+004_13:35:00	on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7DA0 # E_Fix_Bias_param_2
					LAP bias stepping P1: A0 = -32 = -11 nA	

	776	+004_13:36:00	on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7DA3 # E_Fix_Bias_param_2
					LAP bias stepping P1: A3 = -35 = -12 nA	

	777	+004_13:37:00	on	ARPF390A # RPC LAP Set Bias
				--- 	
				VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2
				VRPD3055 = 0x0000 # IO_Poke_param_3
				VRPD3050 = 0x7DA6 # E_Fix_Bias_param_2
					LAP bias stepping P1: A6 = -38 = -13 nA	

	778	+004_13:38:00 12_ 05:38	on	ARPF390A # RPC LAP Set Bias	LAP bias P1 -5 nA, P2 +1 nA	

				--- VRPD3046 = 0x0000 # Denisty_Fix_Bias_param_2 VRPD3055 = 0x0000 # IO_Poke_param_3 VRPD3050 = 0x7D8E # E_Fix_Bias_param_2	Back to nominal bias at end of P1 bias stepping.	
H	780	+004_13:40:00 12_05:40	on	ARPS809A # LAP Mode Change --- VSK01262 = SID2 [ENG] # ModeLAP VSK01267 = 0x45 # LAParam VSK01269 = 0x0005 # LAP EEPROM Boot Bank	LAP sweeps and cont current for photoemission determination (macro 505) Vbias +10 V	
I	782	+004_14:30:00 12_06:30	on	ARPS809A # LAP Mode Change --- VSK01262 = SID2 [ENG] # ModeLAP VSK01267 = 0x04 # LAParam VSK01269 = 0x0005 # LAP EEPROM Boot Bank	LAP offset determination (macro 104)	
J	785	+004_14:55:00 12_06:55	on	ARPS809A # LAP Mode Change --- VSK01262 = SID2 [ENG] # ModeLAP VSK01267 = 0x73 # LAParam VSK01269 = 0x0005 # LAP EEPROM Boot Bank	LAP to quiet LDL mode (macro 803, Vbias P1 +10 V)	
	790	+004_15:00:00	on	ARPS496A # Load MIP Cfg Table --- VRPG4001 = 0x2600 # Load_Config_detail_1 VRPG4002 = 0x0011 # Load_Config_detail_1 VRPG4003 = 0x0205 # Load_Config_detail_1	MIP to LDL (executes 5 minutes after LAP LDL setting)	
	795	+005_08:00:00	on	ARPS496A # Load MIP Cfg Table --- VRPG4001 = 0x2600 # Load_Config_detail_1 VRPG4002 = 0x0051 # Load_Config_detail_1 VRPG4003 = 0x0205 # Load_Config_detail_1	MIP in LDL transmitting level : divided by 2	
	800	13_16:00			RPC off	

Table 2. Details of LAP (and RPC) operations planning for the Lutetia flyby.

4 Data

4.1 Blocks A and H: bias voltage sweeps

Block A: 100707 16:10 - 23:10
Block H: 100712 05:40 - 06:30

Probe bias voltage sweeps, shown in Figure 5, were performed in blocks A and H. The 7 hours of sweep operations in block A are displayed in Figure 4. The effect of varying illumination is seen as sweeps with very varying character are superposed.

Probe 1 shows expected behaviour, with quite stable photoemission and low current when in eclipse, showing that the data are well calibrated and useful. However, probe 2 displays a different behaviour: here, there seems to be a constant offset of some -7 nA to the data. Deducting this remaining offset, the photoemission saturation current is around -9 nA on both probes, and the data points for probe 2 cluster around zero when the probe is in eclipse (the almost horizontal branch in Figure 4 below).

What could cause such an offset? It is not due to incorrectly determined electronics offsets. Figure 5 show the offset determinations in blocks B and I, giving very consistent results, particularly for probe 2. It should be noted that these offsets are determined immediately after the sweeps in blocks A and H are recorded. Furthermore, the eclipse sweeps for probe 2 from block H are very similar to those seen in Figure 4 (block A). This means that this extra offset is stable over more than four days, and cannot be blamed on some issue like the instrument not having reached thermal equilibrium or similar. Finally, the data shown here were calibrated manually, while the LAP archiving software gives very similar results (not shown): hence, the problem is not due to any issue of the calibration software. Further investigations will be necessary.

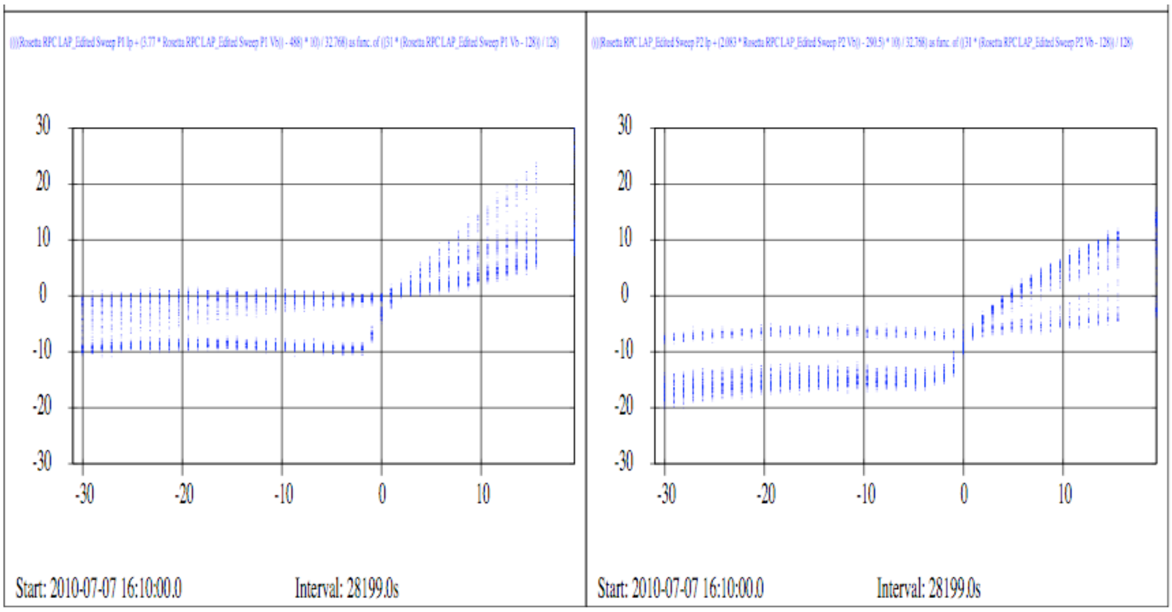

Figure 4. All LAP probe bias sweeps in block A (100707 16:10 - 23:10). P1 at left, P2 at right. Horizontal axes are bias voltage in volts, vertical axes measured current in nA.

4.2 Blocks B and I: Offset determination

Block B: 100707 23:10-23:30
Block I: 100712 06:30 - 06:55

Good data were obtained in both blocks (Figure 5). If the current offsets y (in TM units) depend on the bias voltage (in DAC digital values) as y = k x + m, the two blocks give:

Block B:
P1: k = -3.7986, m = 491.6788
P2: k = -2.1151, m = 295.1438
Block I:
P1: k = -3.6325, m = 469.9852
P2: k = -2.1224, m = 296.2596

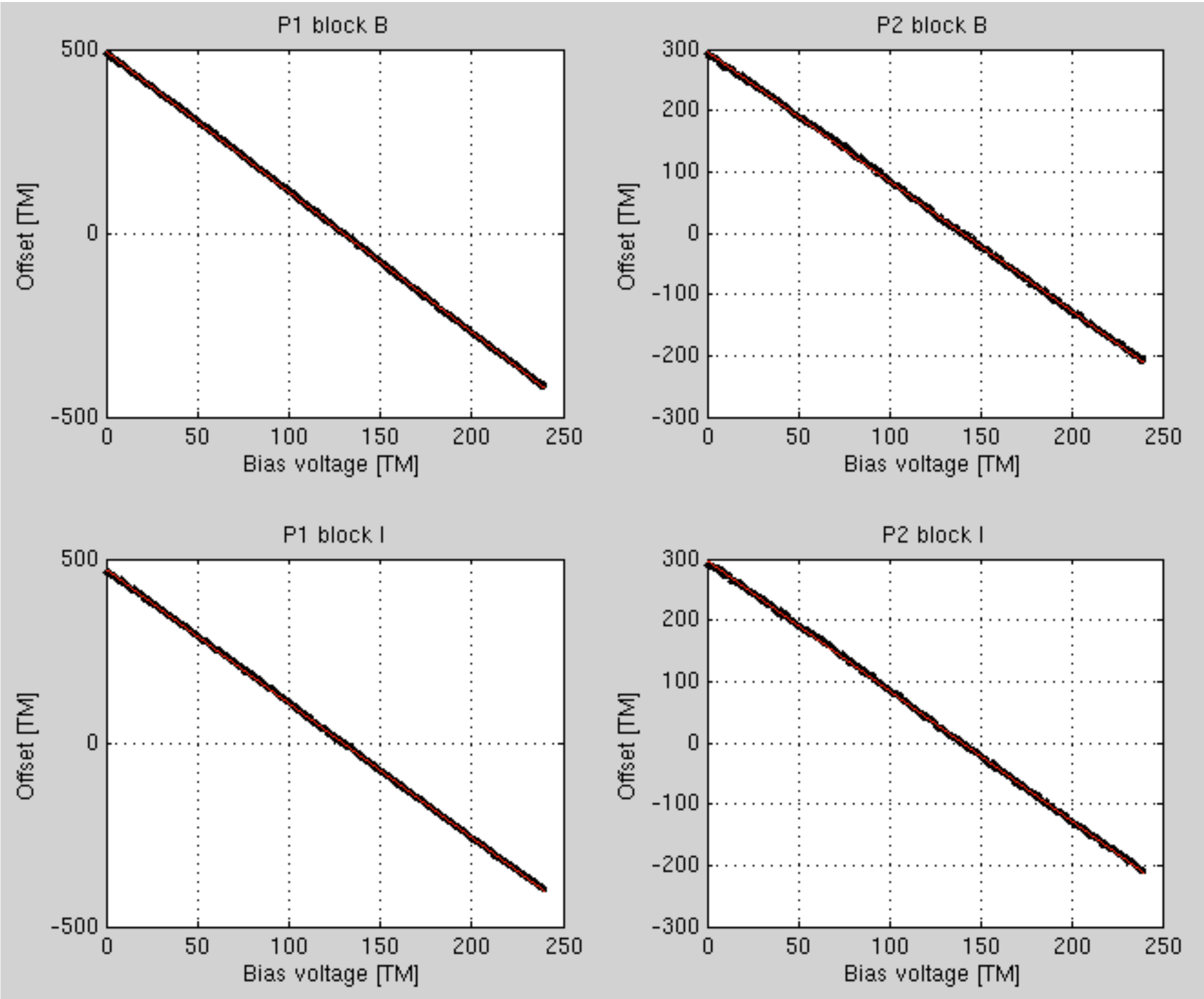

Figure 5. Offset determination sweeps in blocks B and I.

4.3 Blocks C and D: Science operations before closest approach

Block C (NM): 100707 23:30 - 100710 12:54
Block D (BM): 100710 12:54 - 16:50

Figure 6 gives an overview of the main science data upstream of Lutetia, with the pointing inserted below. The large jumps in the data close to changes of the solar aspect angle (black curve in bottom panel) are due to bias changes in response to illumination changes. The substantial jumps in P1 voltage when the Y axis pointing changes (blue vertical lines) are interesteing, but it should be noted that P1 is in shadow at these times: the best data comes from the sunlit probe P2, which shows smaller signatures of these changes.

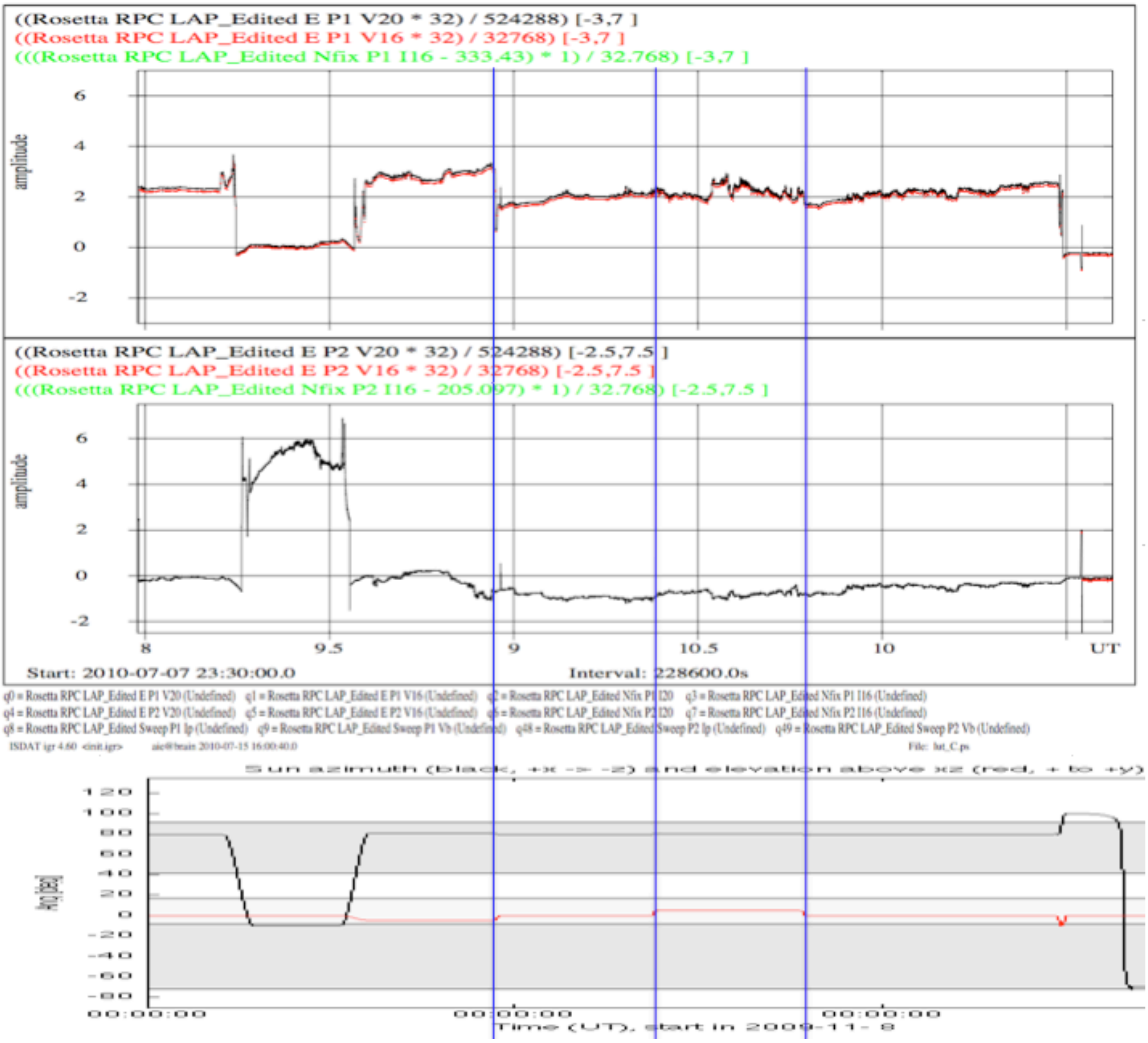

Figure 6. LAP probe voltages (in volts) for P1 (upper panel) and P2 (centre panel) during the approach to Lutetia, with spacecraft pointing as in Figure 2 (lower panel). Blue vertical lines indicate some of the times when the pointing of the s/c Y axis (red line in lower plot) changes. In the top plot, red is 16-bit snapshots at 18.75 kHz sampling frequency, black 20-bit voltages at 57.8 Hz.

4.4 Block D: Closest approach

100710 12:54 - 16:50

Figure 7 gives an overview of the data gathered with burst TM rate (BM), in formats as in Figure 6. Closest approach is close to 15:46.

Data are nominal, exept for the data gap for some minutes after 17:00, which may be due to data lost when dumping s/c memory to ground. RPC has requested a re-dump of these data.

The 16-bit data, gathered at 18.75 kHz and plotted in red, shows a high noise ratio after 16:54. This is expected, as MIP is in LDL mode here, which is known to give some noise in the first samples of each record of these data.

The attitude and the bias settings in response to its changes are discussed in Table 3.

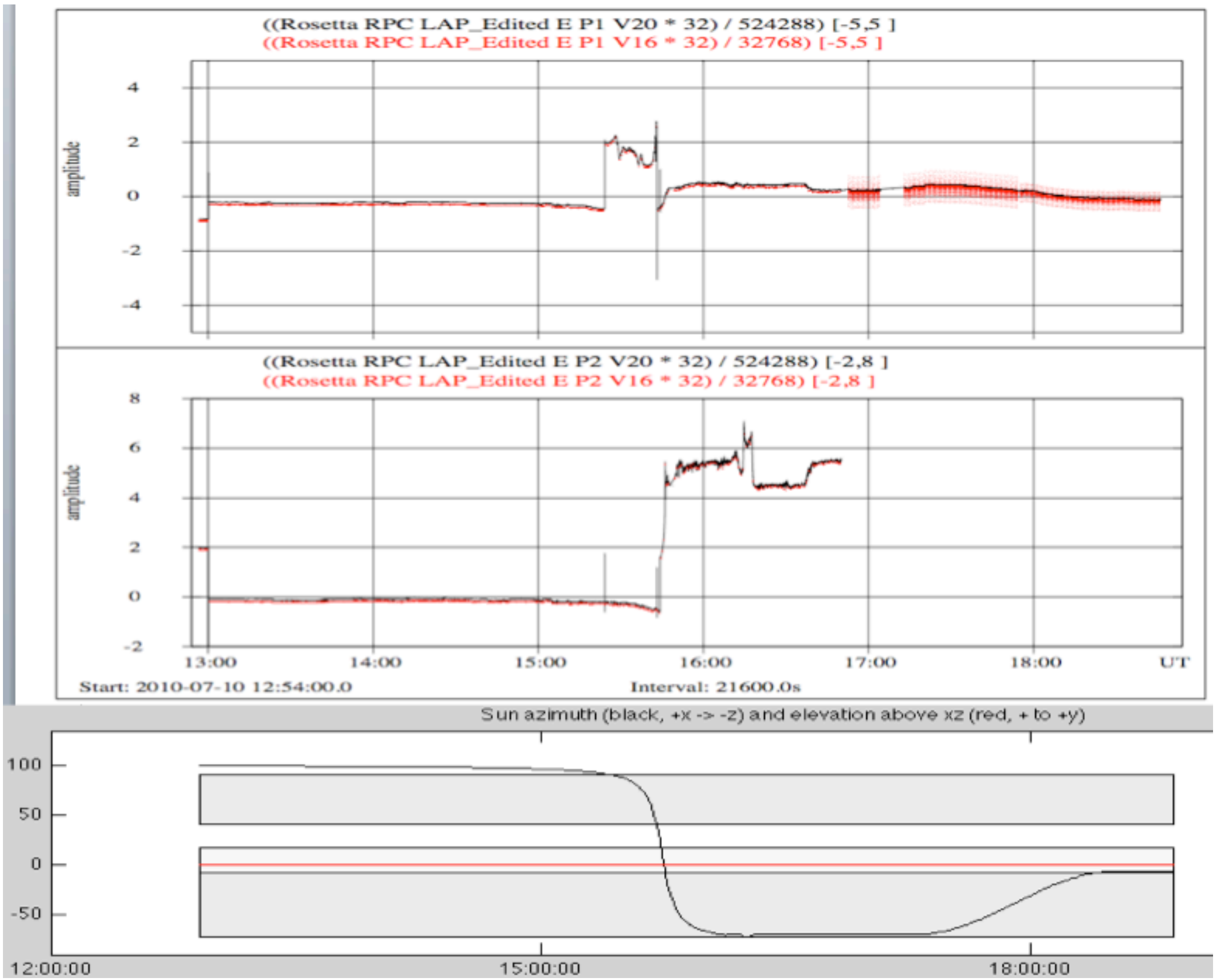

Figure 7. Probe 1 and 2 voltages (in volts) during a period of solar aspect angle around 100 degrees. In the two upper plots, red indicates 16-bit snapshots at 18.75 kHz sampling frequency, while black is 20-bit voltages at 57.8 Hz.

Figure 8 zooms in on the data around closest approach. While the P2 data in particular are of course affected by the bias and illumination change, P1 data shows a nice and smooth behaviour with solar wind features clearly showing. The used settings thus seem to be well adapted for the Lutetia flyby. It should be noted that s/c outgassing due to previously not illuminated surfaces heating up and releasing water vapour and other compounds into space may be responsible for several large scale features (see Schläppi et al., *Journal of Geophysical Research, 115*, A12313 (2010), doi:10.1029/2010JA015734).

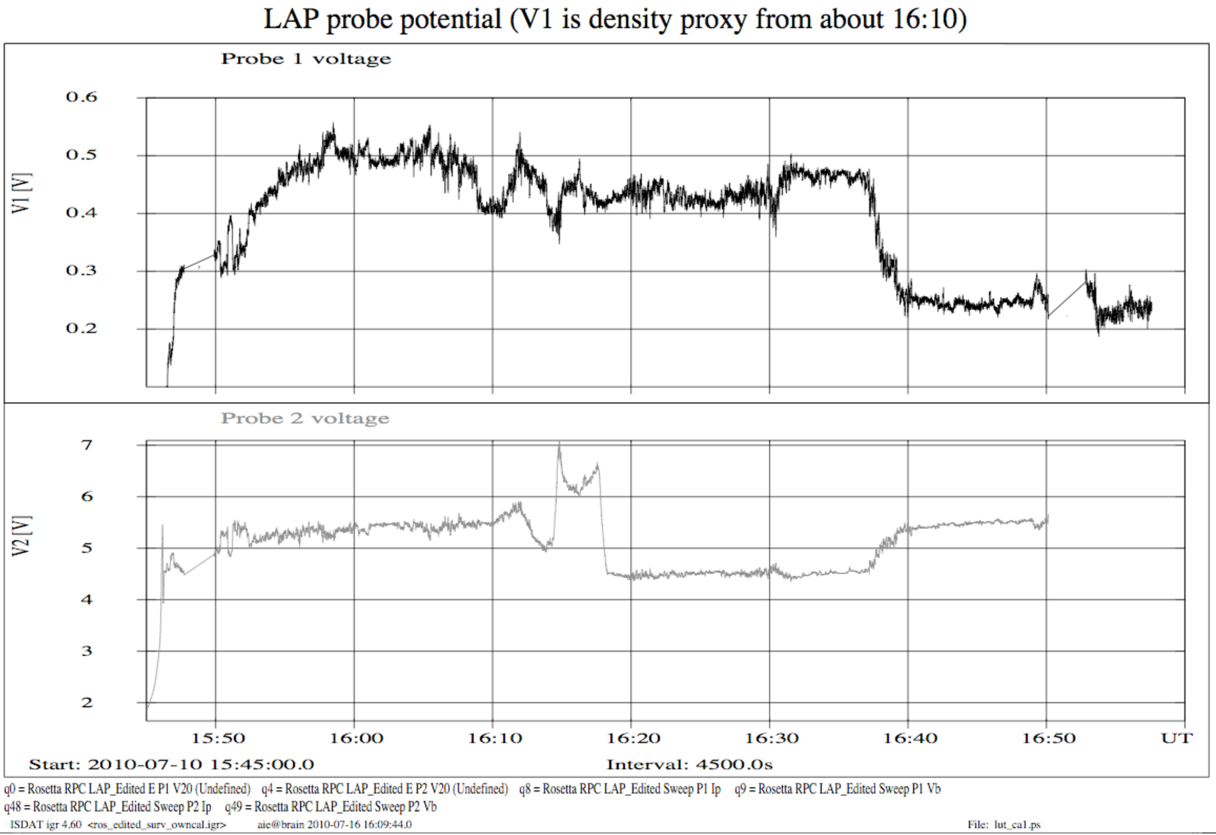

Figure 8. Probe 1 and 2 voltages (in volts, sampeld at 57.8 Hz) around closest approach.

4.5 Block E: BM post-asteroid science operations in LDL mode

100710 16:50 - 18:54

The data from this operation are included in Figure 7, starting at 16:50, when P2 is handed over to MIP. As usual when running P1 in voltage mode, noise from MIP can be seen in the P1 data, but only intermittently with good data in between. The data are nominal.

4.6 Block F: NM post-asteroid science operations

100710 18:54 - 100712 05:21

A data overview is shown in Figure 9. All data are nominal. The dominating features are due to illumination changes and associated bias settings.

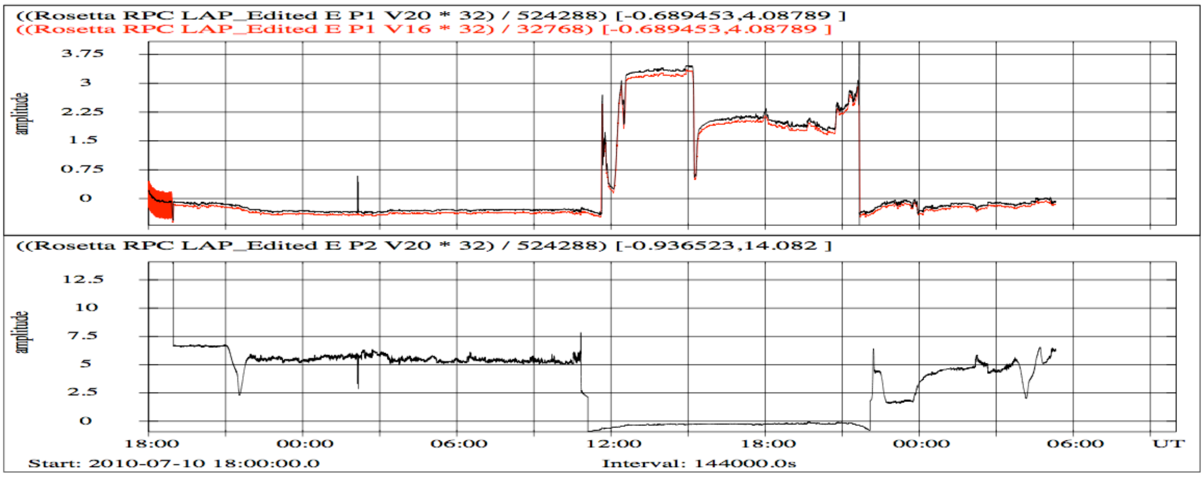

Figure 9. Probe 1 and 2 voltages (in volts) during block F. Red is 16-bit snapshots at 18.75 kHz sampling frequency, black 20-bit voltages at 57.8 Hz.

4.7 Block G: bias current stepping

100712 05:21 - 05:40

The first bias steps are shown in Figure 10. The data are nominal, and the voltage response to P1 bias current change is clearly seen.

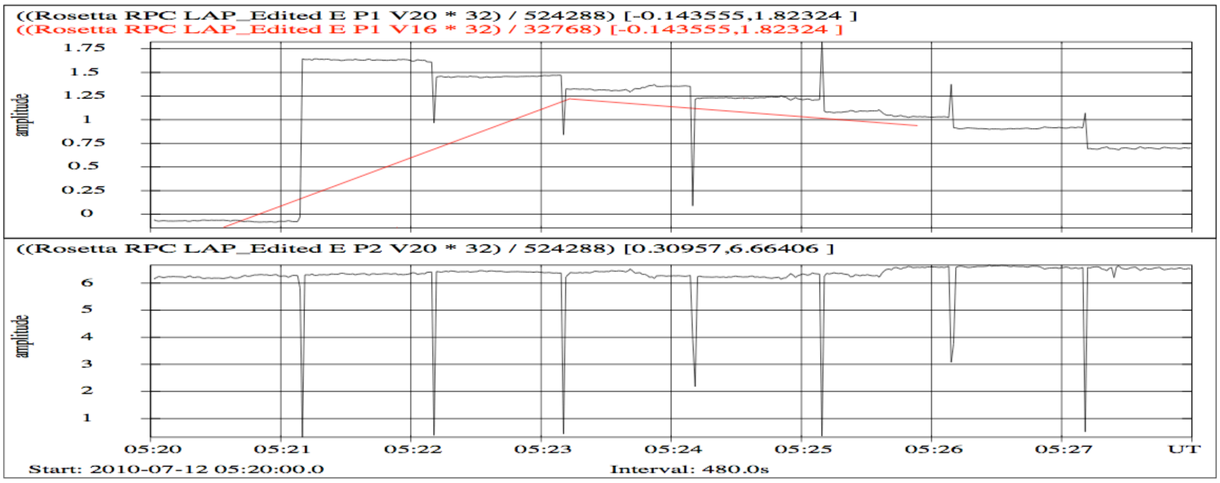

Figure 10. Probe 1 and 2 voltages (in volts) during bias current stepping on P1 (block G). Red is 16-bit snapshots at 18.75 kHz sampling frequency, black 20-bit voltages at 57.8 Hz.

4.8 Block J: LDL quiet mode

100712 06:55 - 100713 16:00

An overview is shown in Figure 11. The data are nominal. The quantization steps are clearly seen, as expected for the low currents in the solar wind. There is little noise from MIP, also consistent with expectations as MIP should not perturb LAP in voltage bias mode.

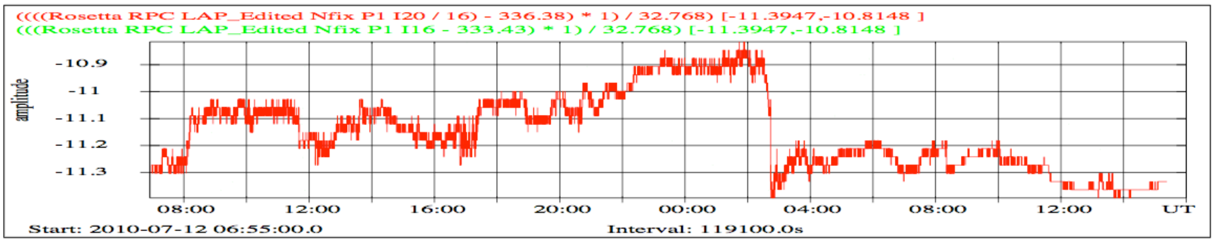

Figure 11. Probe 1 current (in nA) during block J .

5 Conclusion

LAP worked as intended during the Lutetia flyby, and data are of nominal quality except for an offset current of around 7 nA on probe 2 only. As discussed in Section 4.1, this cannot be due to incorrect compensation for the LAP electronics offsets.

As expected, there are no immediately striking signatures of asteroid interaction, though it is still possible that something might be revealed in a full analysis. The commanding has been verified in data, and all settings seem to be well adapted for the operations. The goals of the operation were thus met.