ALCATEL SPACE

HUYGENS

TITLE : Probe performance analysis

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1. PURPOSE

The objective of this document is to deliver an assessment of the **Probe health status** and **Probe overall performances** during the mission.

Detailed performance analysis is not the purpose of this document.

2. APPLICABLE DOCUMENTS

The applicable documents are :

[Mission] Probe mission data
AlcatelMVDA_Mission.zip 15/01/2005 13:22

The reference documents are :

[Analysis] POSW mission analysis plan
HUY.ASP.MIS.PL.0002

3. MISSION SUMMARY

The HUYGENS Probe has been awaken the 14th of January 2005, seven years after its launch and 4h30mn before entry into the TITAN atmosphere.

The end of the entry has been detected at 09:10 am with the T_0 event detected. At this the point the aerodynamic conditions allowed the parachute deployment and the front shield release.

The Probe started to emit at 09:11 am, its data being recorded by the CASSINI Orbiter.

The descent lasted 2 hours 28 mn and ended at 11:38 am. The Probe has survived the impact and has continued to provide data for more than 1 hour until the Orbiter disappeared at the horizon.

The Probe dynamical characteristics during the entry and descent as acceleration, altitude and spin, where within the expected range.

The Probe's software and equipments worked without failure.

Unfortunately, due to an error of the operator, one of the two redundant data channels were not recorded. Nevertheless it should not degrade the scientific objective. The only experiment which could have been affected, will be recovered thanks to the radio-telescopes which was listening the Probe signal from Earth.

4. PROBE DATA ANALYSIS

4.1 HEALTH STATUS

4.1.1 PSA START-UP

Summary :

At start-up the SASW performed hardware checks and reported its initialisation status, no failure were reported. Both the PSA hardware and SASW software were healthy for the two redundant chains.

Detailed :

The following parameters were representative of the correct PSA B hardware power on and SASW software initialisation :

UTC	TM code	TM name	TM value	Comment
06:50:50	R6003C	PSA B ID	PSA_B	
06:50:50	A2005H	PSA B EXCEPT CNT	0000	
06:50:50	A2003H	PSA B FIX OVFL	0000	
06:50:50	A2004H	PSA B FLOAT OVFL	0000	
06:50:50	A2008H	PSA B INIT STAT	HEALTHY	
06:50:50	A2001H	PSA B INV TC CNT	0000	
06:50:50	A2006H	PSA B OVRR CNT	0000	
06:50:50	A2001W	CPU B FAULT REG	OK	
06:50:50	A20071	EDAC B DBL ERR	NO_DBL_ERR	
06:50:50	A20070	EDAC B SGL ERR	NO_ERROR	
06:50:50	A2002W	RAM FF ADD B	0000	
06:50:50	A2009H	BIU FAIL CNT B	0000	
06:50:50	A2010W	BIU FAIL REG B	NO_FAILURE	
06:50:50	A2009W	BIU RAM FF ADD B	0000	
06:50:50	A2003W	SASW B HLT LSW	OK	
06:50:50	A2004W	SASW B HLT MSW	OK	
06:50:50	A2005W	SASW B PROM CHK	0000	
06:52:17	A2006W	SASW B HWM	7068 (14%)	Criteria : < 80%

4.1.2 PROBE START-UP

Summary :

At start-up the POSW performed hardware checks and reported its initialisation status. No failure were reported on chain B, both the CDMU B hardware and POSW software were healthy.

There is no data from chain A. However all the experiments reported chain A valid, this means that all checks at start-up where OK and that no failure where detected later on by the software.

Detailed :

The following parameters were representative of the correct CDMU B hardware power on and POSW software initialisation :

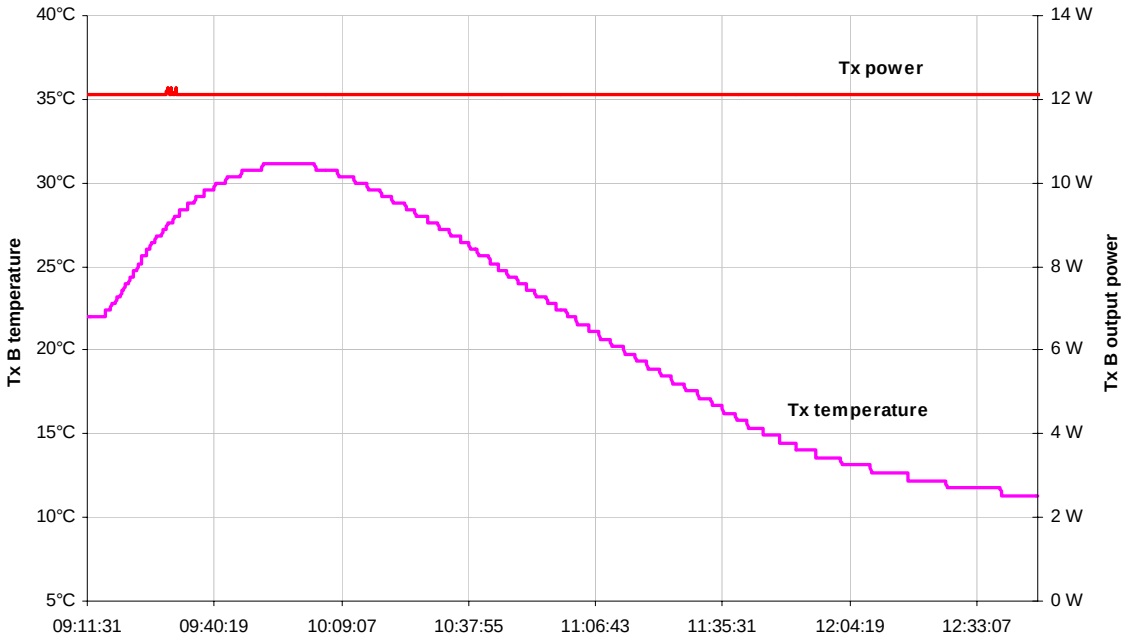
UTC	TM code	TM name	TM value	Comment
09:11:22	S2010H	CDMU INIT STAT B	HEALTHY	
09:11:23	S2007H	OVERRUN CNT B	0000	
09:11:23	S2006H	EXCEPTION CNT B	0000	
09:11:23	S2001H	RAM SNG ERR B	0000	
09:11:23	S2008H	RAM DBL ERR B	0000	
09:11:23	S2002H	INVALID TC CNT B	0001	No Inhibition TC
09:11:23	S2003H	VALID TC CNT B	0002	Predefined ACP TCs in MTT
09:11:24	S2016W	CPU B FAULT REG	HEALTHY	
09:11:24	S2004H	FXD POINT OVFL B	0000	
09:11:24	S2005H	FLT POINT OVFL B	0000	
09:11:24	S2017W	RAM FIRST FAIL B	#FFFF#16	No failure
09:11:24	S2018W	POSW B PROM CHK	0000	
09:11:24	S2020W	POSW B INIT TIME	1.89 s	Criteria : < 6.5 s
09:11:25	S2023W	POSW B HLT MSW	HEALTHY	
09:11:25	S2022W	POSW B HLT LSW	HEALTHY	
09:11:25	S20134	CDMU CHAIN B	CHAIN_B	
09:11:25	S20135	PROC VAL PORT B	VALID	
09:11:25	S2019W	POSW B HIGH WTR	7425 (10%)	Criteria : < 80%

4.2 DATA LINK PERFORMANCE

4.2.1 TRANSMITTED SIGNAL

Summary :

The Transmitter output power was constant 12.1 W.

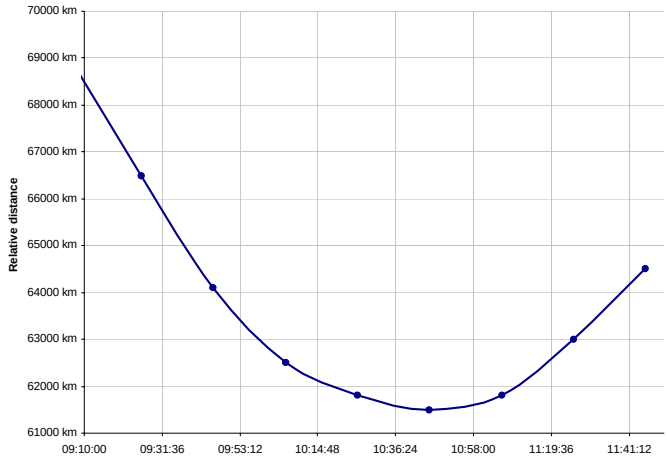


4.2.2 RECEIVED SIGNAL

4.2.2.1 AGC

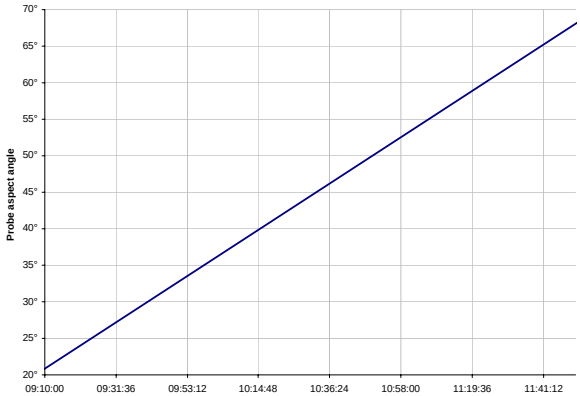
Summary :

The received signal varies during the descent due to the relative distance between the Probe and the Orbiter : $\Delta P_{dB} \approx \pm 20*\log(\Delta d)$.

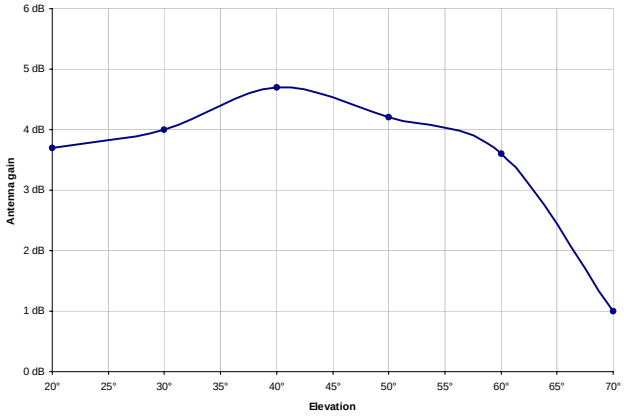


Relative distance

The elevation (Probe aspect angle) impacts directly the received power due to the Probe Antenna gain pattern.



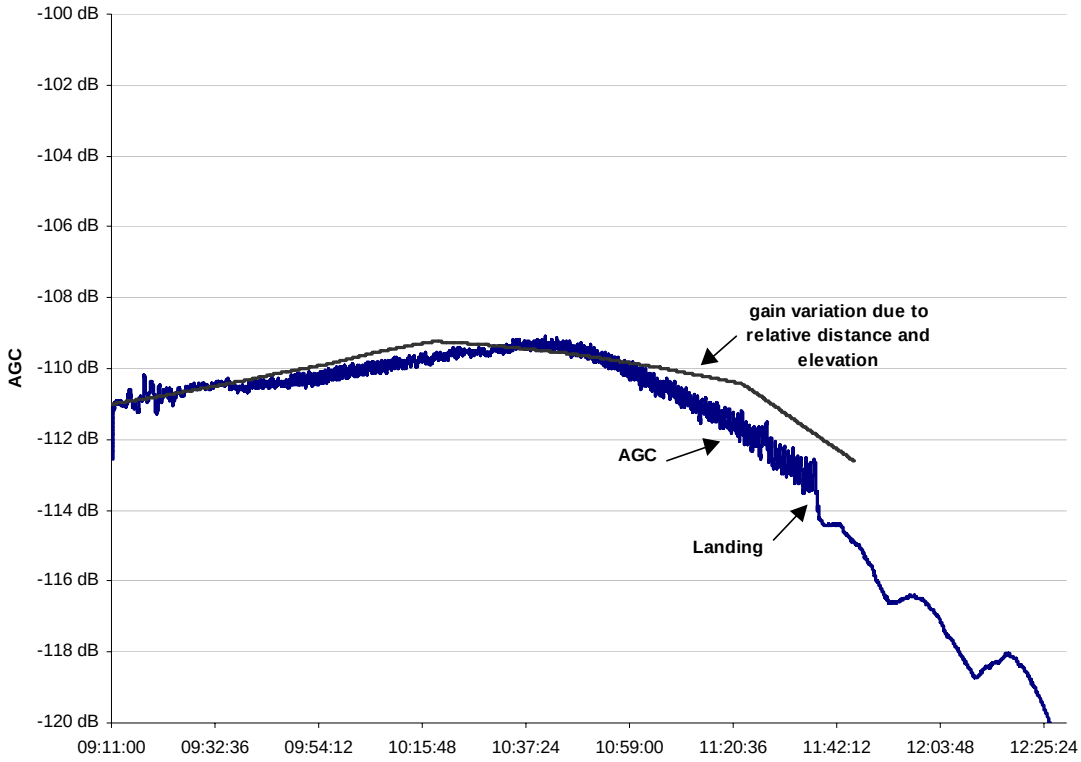
Elevation



Antenna pattern

Some other geometry dependant parameters have also a smaller impact on the received power.

The AGC profile is consistent with the gain variation due to the relative distance and elevation.

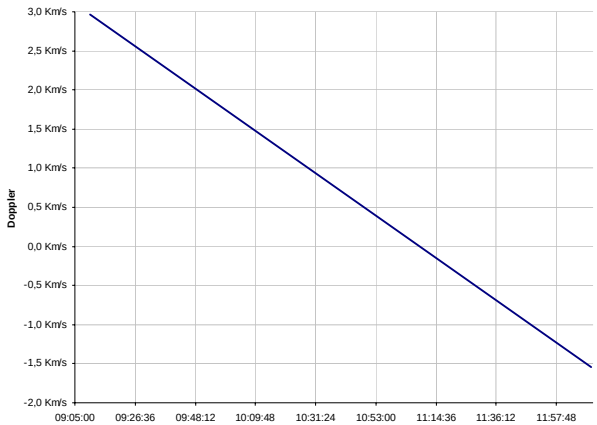


AGC

4.2.2.2 NCO

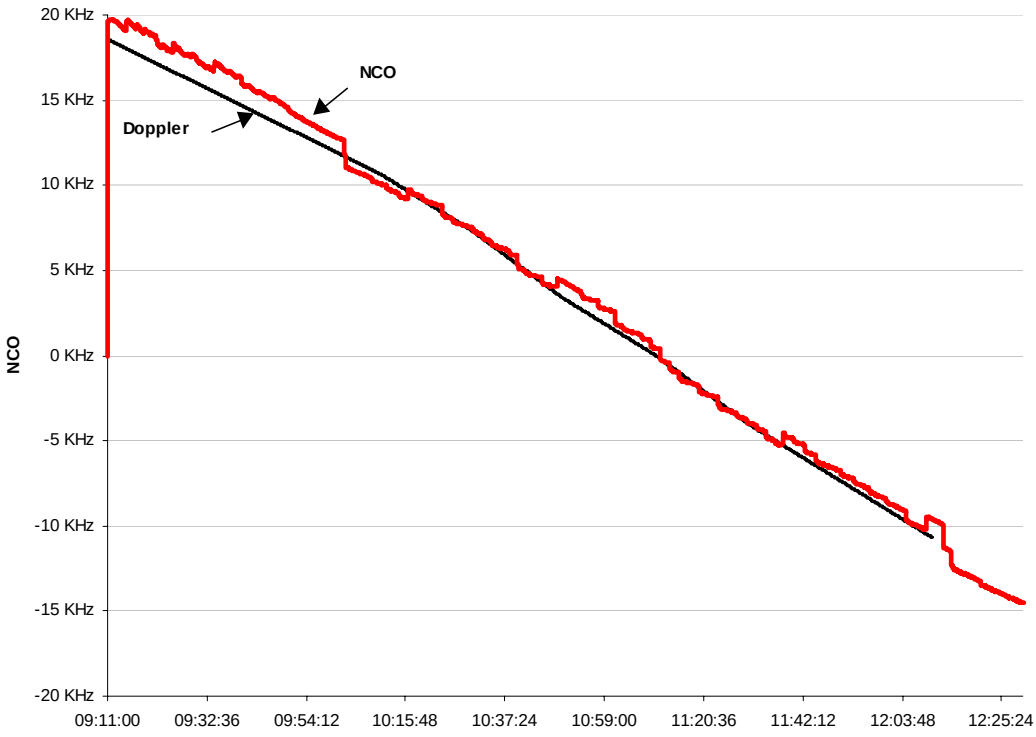
Summary :

The relative motion between the Probe and the Orbiter will induces a doppler :
$\Delta f \approx \pm \Delta v * f_o / c$ with $c \approx 3*10^8$ m/s, $f_o \approx f_{carrier}$ 2 GHz



Doppler

The observed frequency shift observed on NCO is closed to the expected doppler effect.



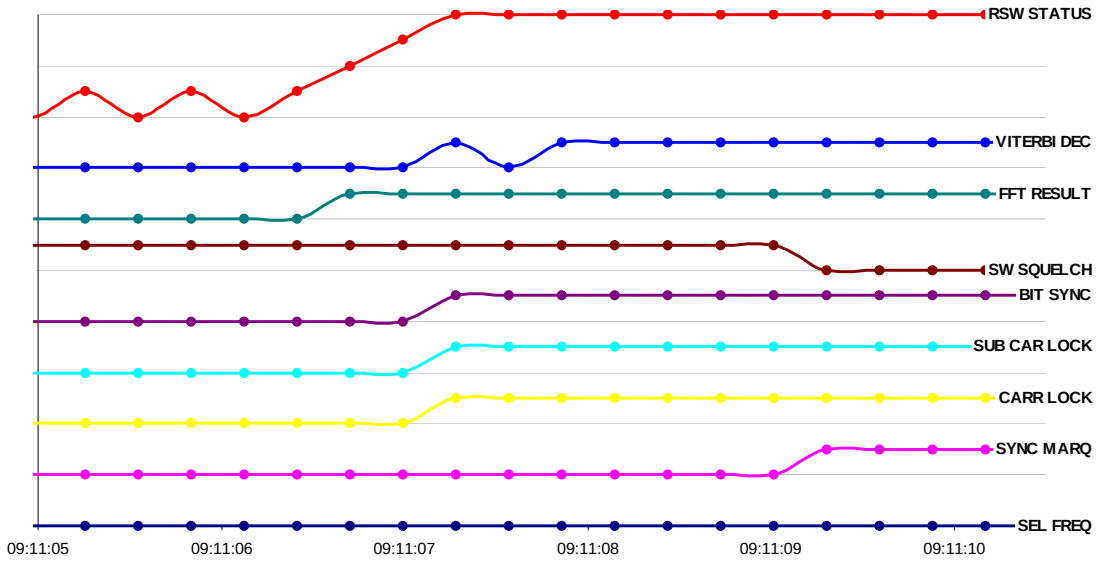
4.2.3 RECEIVER LOCK

Summary :

The Probe started to emit data at 09:11:07 am, after HPA power ON.

The PSA receiver locked two seconds later and stayed locked during all the descent and up to fifty minutes after landing. The data link was lost around one hour after landing when the Orbiter disappeared at the horizon.

Detailed :

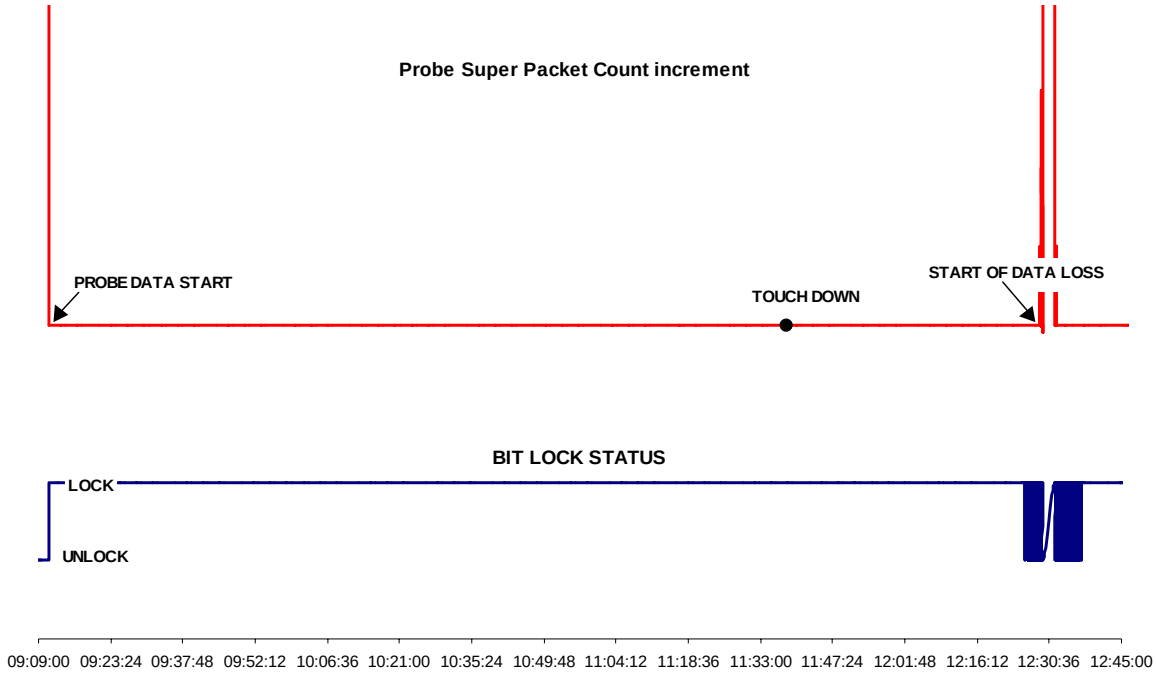


UTC	TM code	TM name	TM value	Comment
09:11:06	R6003A	RSW STATUS B	AGC_NORM_ST	
	R6003A	RSW STATUS B	SIG_DETEC_ST	
	R6001B	FFT RESULT B	PASSED	
	R6003A	RSW STATUS B	C_FR_ACQ_ST	
09:11:07	R6003A	RSW STATUS B	C_PH_ACQ_ST	
	R60019	CARR LOCK ST B	LOCKED	
	R6001C	SUB CAR LOCK B	LOCKED	
	R6004C	BIT SYNCHRO B	LOCKED	
	R60018	VITERBI DEC ST B	LOCKED	
	R6003A	RSW STATUS B	SIG_TRACK_ST	
09:11:09	R6002C	SYNCH MARK ST B	LOCKED	
	R6003B	SW SQUELCH ST B	NOT_ACTIVE	

4.2.4 DATA CONTINUITY

Summary :

The Probe telemetry were recorded with a continuous increment of the Virtual Channel Counter in the Frame header and of the Source Sequence Count in the Housekeeping Packets header. There was no frame nor packet loss during all the descent and around one hour after landing.



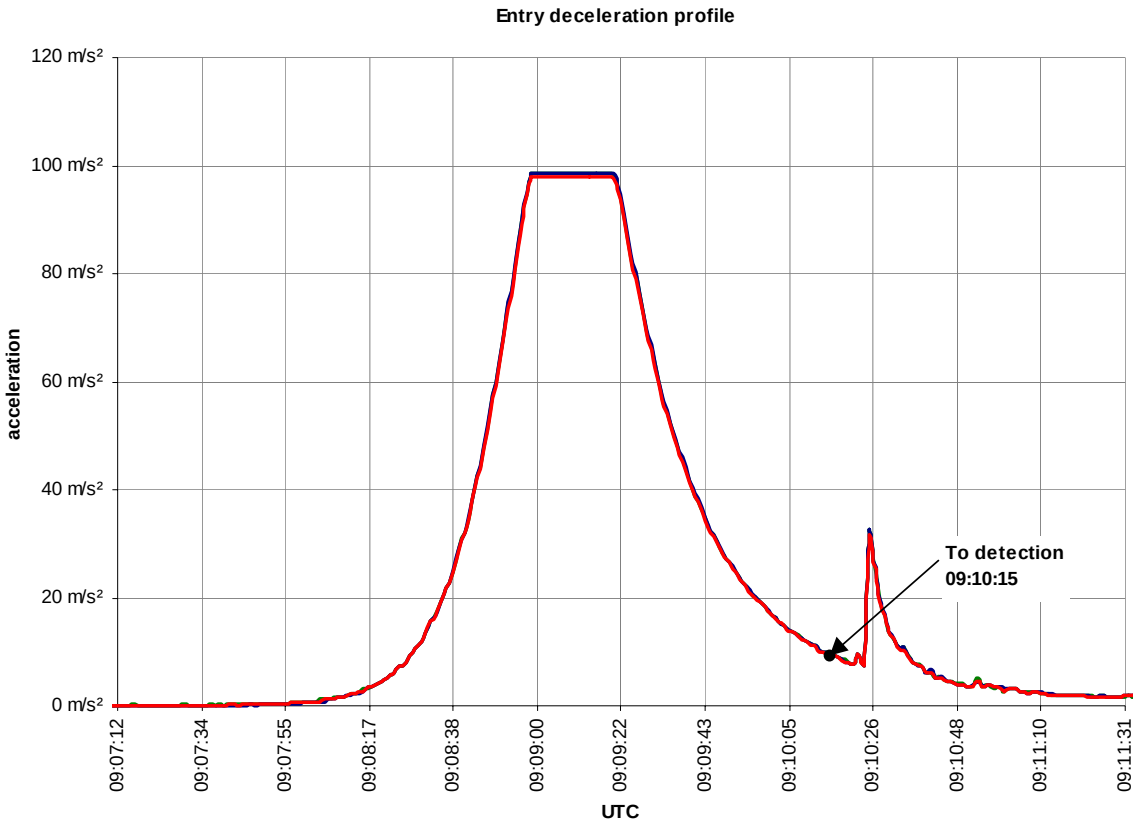
4.3 ENTRY PERFORMANCE

4.3.1 T_0 DETECTION

The Titan's atmosphere entry detection is based on triple redundant accelerometers (CASU). Note that the entry detection by the software is named "S_0", the "T_0" acronym being used for the pilot parachute deployment 6 seconds after S_0 detected.

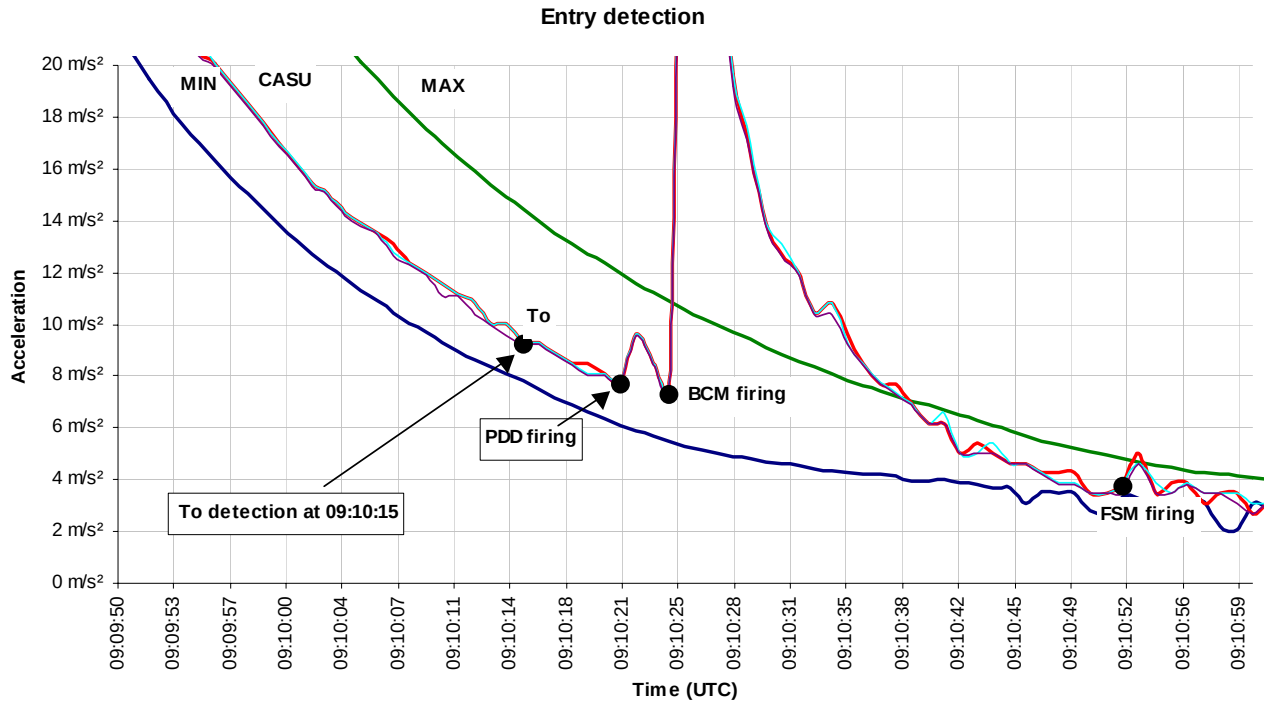
Summary :

The acceleration raised above 100 m/s², for 80 m/s² minimum requested for enabling both T_0 detection by software and T_A detection by hardware.

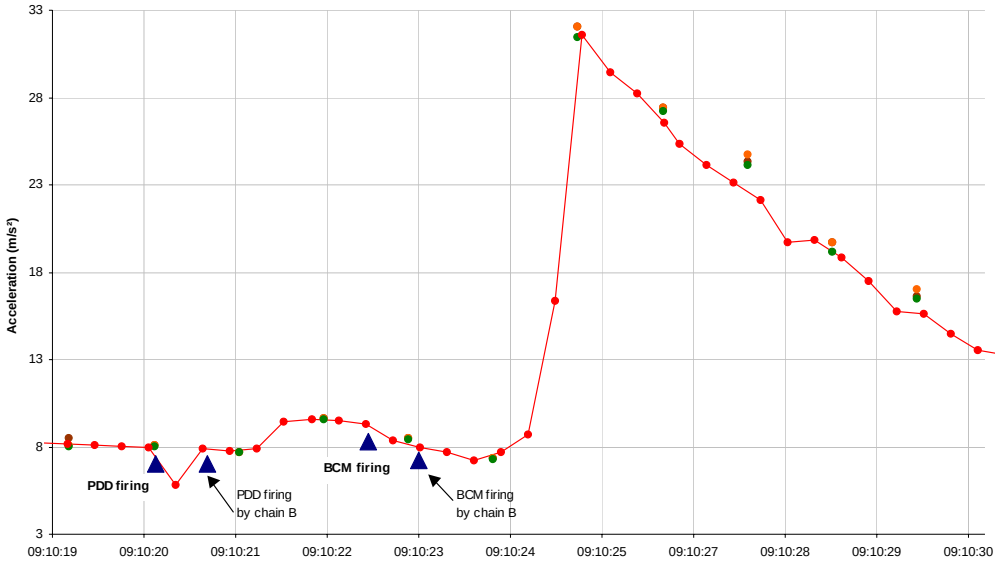


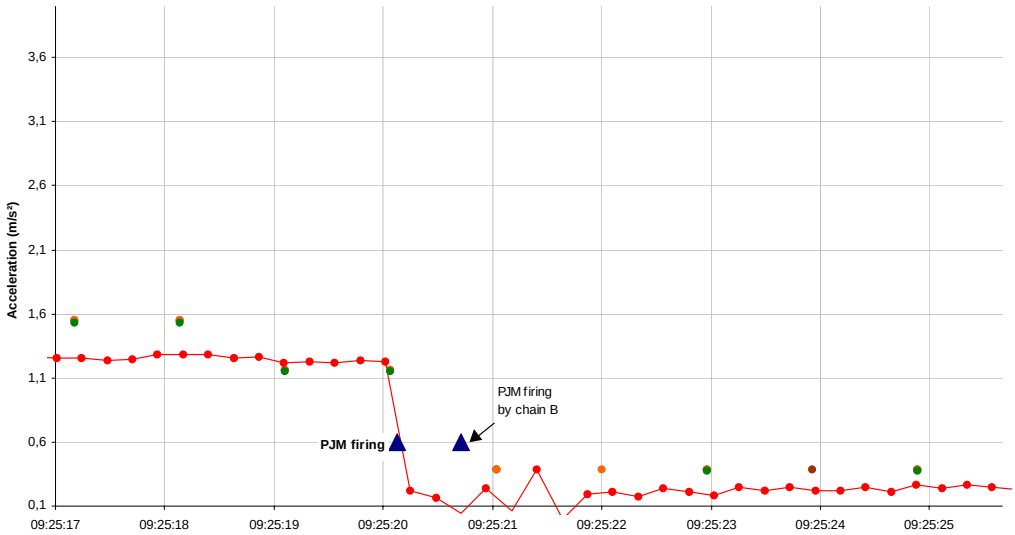
The T_0 event raised well within the expected entry profile.

The S_0 has been declared when the acceleration dropped below 10 m/s², the requirement was 10 m/s²±5%. The Pilot Parachute (PDD) has been fired (T_0 event) at 7.7 m/s². The requirement was between 9.5 m/s² (after T_A detection) and 7.2 m/s² (in order to ensure the aerodynamic conditions for the parachute deployment and the front shield release).



The S_0 event is dated precisely by the chain B “Real Time” and “Mission Time” counters. However it can be observed, thanks to the accelerometer sensors, that the pyro firing orders are around 0.6 s in advance with respect to the theoretical time. This suggests that the S_0 has been detected by chain A first. The 0.6 s interchain delay is below the requirement of 2.2 s max.





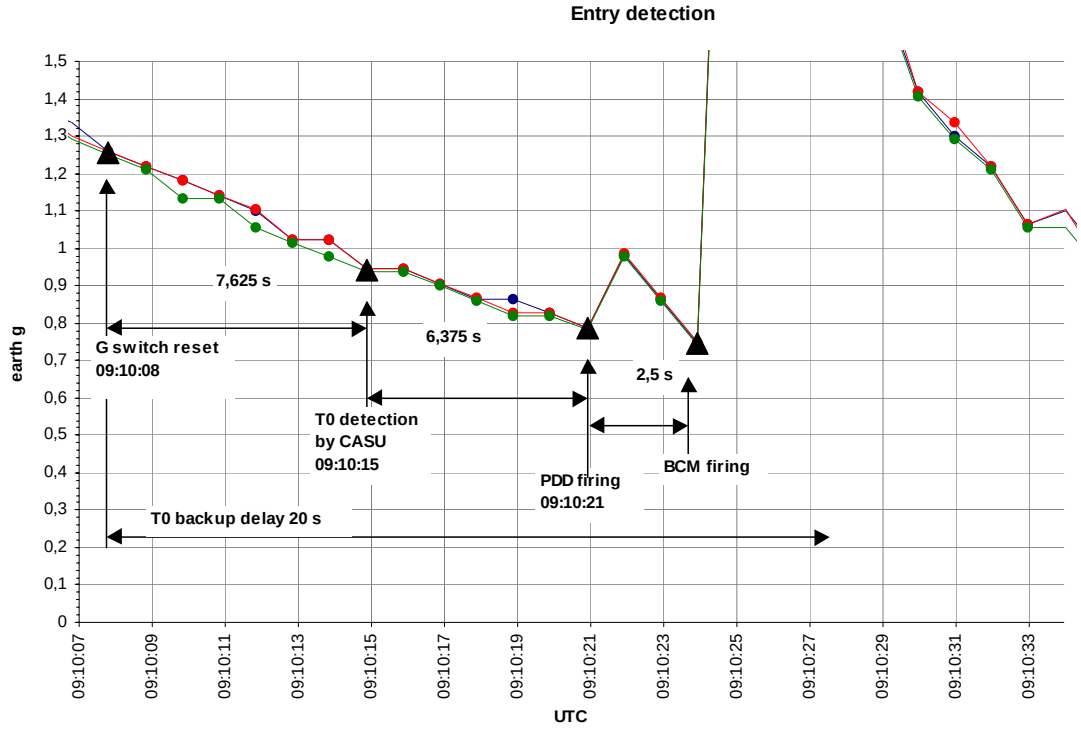
Detailed :

UTC	HBHK44 RTC	HBHK45 MTC	D7004A CASU 1 (m/s²)	D7005A CASU 2 (m/s²)	D7006A CASU 3 (m/s²)	Event
09:10:08	04:28:34	04:28:34	12,355	12,362	12,277	To backup
09:10:09	04:28:35	04:28:35	11,969	11,975	11,893	
09:10:10	04:28:36	04:28:36	11,583	11,589	11,126	
09:10:11	04:28:37	04:28:37	11,197	11,203	11,126	
09:10:12	04:28:38	04:28:38	10,811	10,817	10,358	
09:10:13	04:28:39	04:28:39	10,039	10,044	9,975	
09:10:14	04:28:40	04:28:40	10,039	10,044	9,591	
09:10:15	04:28:41	00:00:00	9,267	9,272	9,207	So detection
09:10:16	04:28:42	00:00:01	9,267	9,272	9,207	
09:10:17	04:28:43	00:00:02	8,881	8,885	8,824	
09:10:18	04:28:44	00:00:03	8,495	8,499	8,440	
09:10:19	04:28:45	00:00:04	8,495	8,113	8,056	
09:10:20	04:28:46	00:00:05	8,109	8,113	8,056	
09:10:21	04:28:47	00:00:06	7,723	7,727	7,672	PDD firing
09:10:22	04:28:48	00:00:07	9,653	9,658	9,591	
09:10:23	04:28:49	00:00:08	8,495	8,499	8,440	
09:10:24	04:28:50	00:00:09	7,337	7,340	7,289	BCM firing

4.3.2 T_0 BACKUP

Summary :

The backup counter started 1 s after g-switch reset (below 12 m/s²) and stopped 6.6 s later when the nominal T_0 has been detected. The backup T_0 was designed to raise 20 s after g-switch reset.



Detailed :

UTC	TM code	TM name	TM value	Comment
09:04:58	S2024W	T0/Ta G-S 1/2 B	0000h	
09:05:02	S2025W	T0 G-S T-OUT B	0	To not detected
09:08:39	S2024W	T0/Ta G-S 1/2 B	FF00h	G-switch1 set 29,5 m/s²
09:08:49			FFFFh	G-switch2 set 59,8 m/s²
09:09:33			FF00h	G-switch2 reset 54,5 m/s²
09:10:07			0000h	G-switch1 reset 12,8 m/s²
09:10:15	S2025W	T0 G-S T-OUT B	6.625 s	Back-up count stop

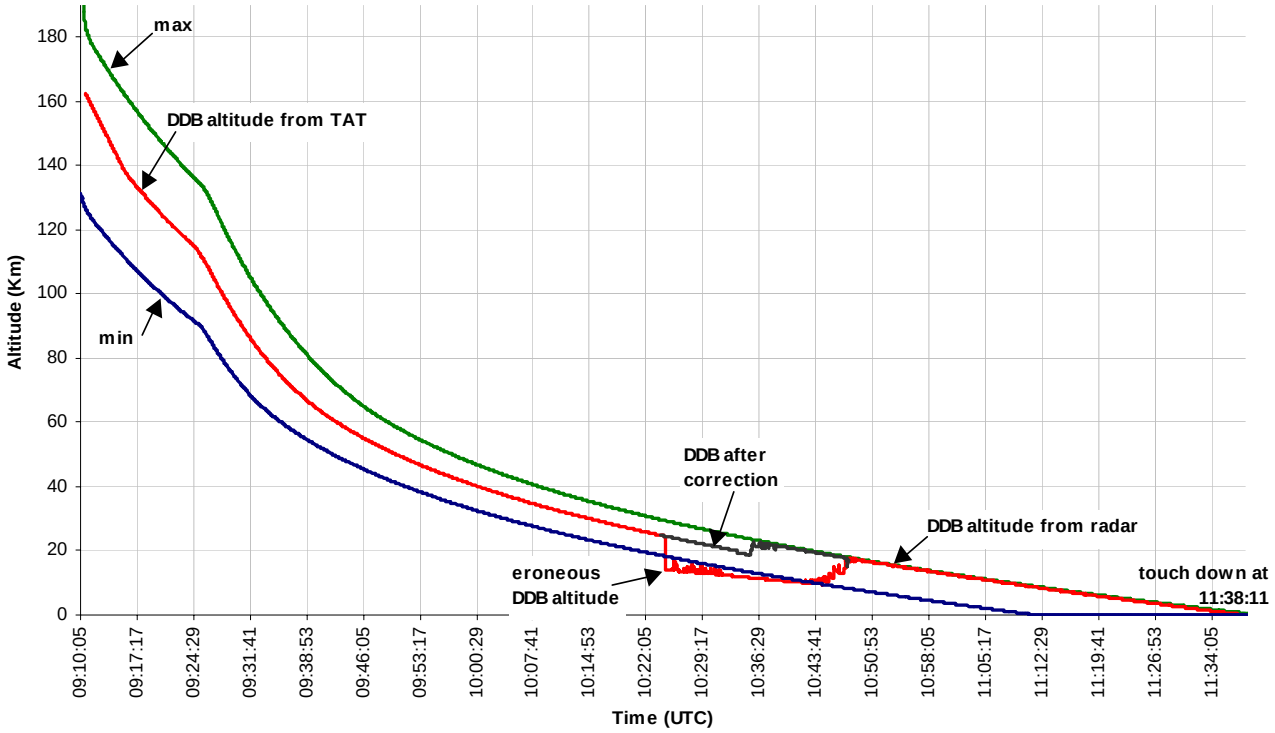
4.4 DESCENT PERFORMANCE

4.4.1 ALTITUDE

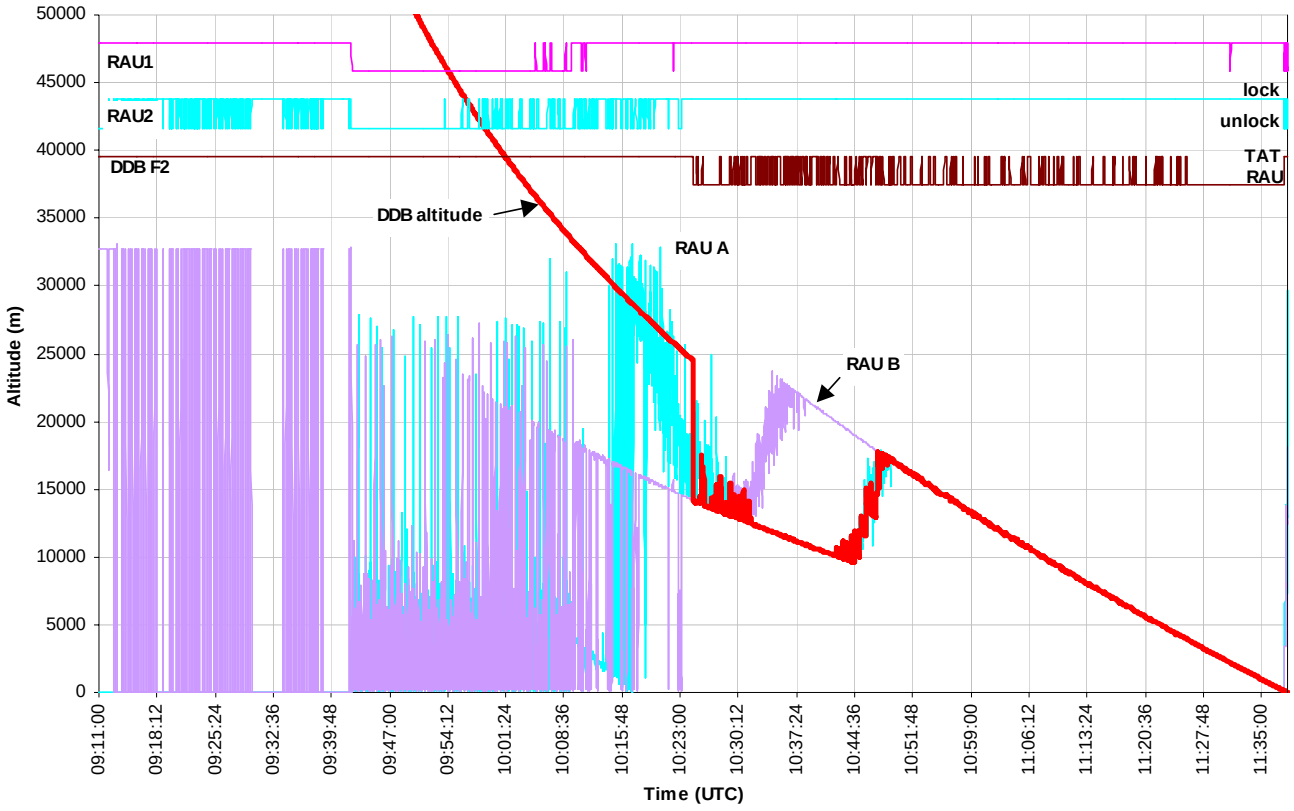
The altitude is predicted from the Time/Altitude Table (TAT) down to 25 Km altitude. Then the altitude is derived preferably from the radar altimeters (RAU).

Summary :

The probe altitude during descent was within the expected entry profile, but closed to the maximum. The time at touch down was 147 mn 52 s after T_0 for 151 mn maximum expected. Between 25 Km to 18 Km the radar altimeters delivered erroneous data.



Down to 25 000 Km the DDB altitude was extrapolated from the TAT. Then the two radars were selected as they were locked but providing incorrect altitude. Below 22 000 Km the RAU B provided correct data but was not selected as RAU A was still incorrect. Below 18 000 Km the two radars worked well and the DDB altitude was accurate.

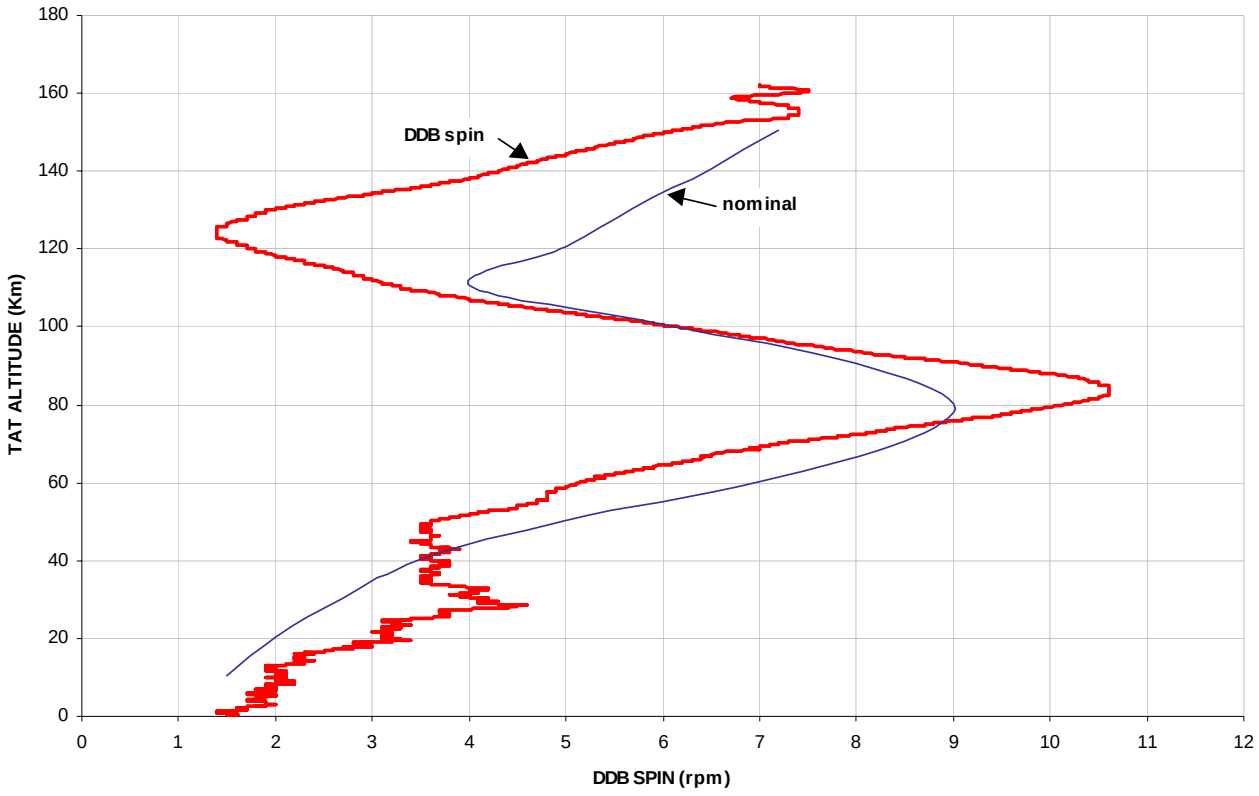


4.4.2 SPIN

The spin rate is computed from Radial Accelerometer.

Summary :

The Probe has been spinned at separation by 7.4 rpm. The spin during entry varied depending of the atmosphere at the altitude considered. The spin was 10.6 rpm max and 1.4 min for a requirement of max 15 rpm (2 rpm below 10 km altitude) and min 1rpm.



4.4.3 MISSION TIMELINE

The pyro firing sequence and subsequent parachutes deployment are scheduled according to pre-programmed Mission Timeline Tables (MTT). The back-cover was released and pilot chute deployed at T_0. Then 2.5 s later the main chute was deployed to stabilise the probe. After 30 s the front shield was released.

Summary :

The telemetry cross-check shows a correct execution of the command timeline. The delay between the command and the observation of it's effect is in line with the telemetry sampling rate, once the link established. The final number of commands is as expected.

Detailed :

CMD Time	CMD Name	TM Time	Delta	TM Name	Value
04:41:35	TUSO R power ON	09:11:22		TUSO R LIMIT ST	ON
04:41:35	TX B power ON	09:11:24		TX B LIMIT ST	ON
04:41:49	GCMS 1 R power ON	09:11:22		GCMS 1 R LIMIT	ON
		09:11:00		GCMS B MODE	RUN_POST_T0
		09:11:00		GCMS B PROC VAL	CDMU_A_ACT
04:59:19	HASI 1 R power ON	09:11:23		HASI 1 R LIMIT	ON
		09:10:48		HASI B MODES	TITAN
		09:10:48		HASI B CDMU ACT	CDMU_A_ACT
09:10:15	**To detection**				
09:10:52	ACP1 R power ON	09:11:22		ACP 1 R LIMIT	ON
		09:11:18		ACP B OP MODE	DESCENT
		09:11:02		ACP B CDMU ACT	CDMU_A_ACT
09:10:54	ACP 2 R power ON	09:11:23		ACP 2 R LIMIT	ON
09:11:01	ACP 3 R power ON	09:11:22		ACP 3 R LIMIT	ON
09:11:07	Pyro 2 GCMS IN set	09:11:22		GCMS IN SRS B	SQUIB SEL
09:11:07	**HPA power ON**				
09:11:11	HASI 2 R power ON	09:11:24	00:00:13	HASI 2 R LIMIT	ON
09:11:11	SSP R power ON	09:11:23	00:00:12	SSP R LIMIT ST	ON
		09:11:20		SSP B PROC VAL	CDMU_A_ACT
09:11:15	Pyro 2 GCMS IN reset	09:11:38	00:00:23	GCMS IN SRS B	SQUIB NO SEL
09:11:15	Pyro 2 GCMS OUT set	09:11:22	00:00:07	GCMS OUT SRS B	SQUIB SEL
		09:11:22		DISR 1 R LIMIT	OFF
		09:11:22		GCMS 2 R LIMIT	OFF
09:11:23	Pyro 2 GCMS OUT reset	09:11:54	00:00:31	GCMS OUT SRS B	SQUIB NO SEL
09:11:24	Pyro 2 DISR cover set	09:11:24	00:00:00	DISR CO SEL B ST	SQUIB SEL
		09:11:24		CMD COUNTER B	34
09:11:28	Pyro 1 and 2 fire A	09:11:40	00:00:12	CMD COUNTER B	35
09:11:41	Pyro 2 DISR cover reset	09:11:41	00:00:00	DISR CO SEL B ST	SQUIB NO SEL

CMD Time	CMD Name	TM Time	Delta	TM Name	Value
09:11:41	DISR 1 R power ON	09:11:54	00:00:13	DISR 1 R LIMIT	ON
		09:11:50		DISR B MODE	INIT
		09:12:54		DISR B MODE	DESCENT
		09:11:56		CMD COUNTER B	37
09:13:21	GCMS 1 R redundant ON	09:13:32	00:00:11	CMD COUNTER B	38
09:13:42	HASI 2 R power OFF	09:13:48	00:00:06	HASI 2 R LIMIT	OFF
09:13:51	ACP 1 R power red. ON				
09:14:01	ACP 3 R power red. ON	09:14:04	00:00:03	CMD COUNTER B	40
09:16:17	ACP 2 R power OFF	09:16:27	00:00:10	ACP 2 R LIMIT	OFF
09:25:17	Pyro 2 PJM set	09:25:30	00:00:13	PAR J3 SRS B	SQUIB SEL
		09:25:30		PAR J2 SRS B	SQUIB SEL
		09:25:30		PAR J1 SRS B	SQUIB SEL
09:25:25	Pyro 2 PJM reset	09:25:46	00:00:21	PAR J3 SRS B	SQUIB NO SEL
		09:25:46		PAR J2 SRS B	SQUIB NO SEL
		09:25:46		PAR J1 SRS B	SQUIB NO SEL
		09:25:32		CMD COUNTER B	43
09:39:13	GCMS 2 R power ON	09:39:22	00:00:09	GCMS 2 R LIMIT	ON
09:42:17	Proximity sensor A ON	09:42:20	00:00:03	PRX SENS B LIMIT	ON
10:32:21	DISR 1 R power red. ON	10:32:28	00:00:07	CMD COUNTER B	44
10:58:21	SSP R power red. ON	10:58:36	00:00:15	CMD COUNTER B	45
11:00:14	DISR 2 R power ON	11:00:27	00:00:13	DISR 2 R LIMIT	ON
11:00:21	ACP 3 R power OFF	11:00:26	00:00:05	ACP 3 R LIMIT	OFF
11:00:22	ACP 1 R power OFF	11:00:26	00:00:04	ACP 1 R LIMIT	OFF
		11:00:28		CMD COUNTER B	47

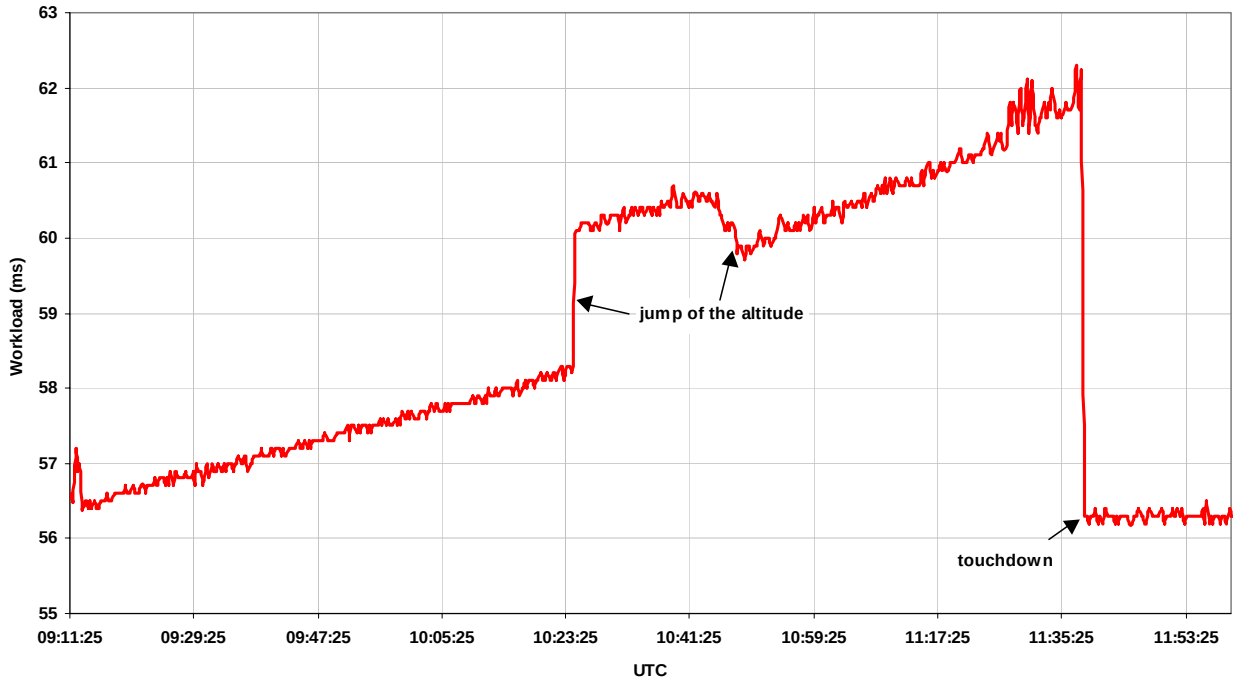
4.5 TIMING MANAGEMENT

4.5.1 PROCESSOR WORKLOAD

Summary :

The processor workload shall be less than 50%, i.e. less than 62 ms, no overrun.

The slope observed is linked to the TAT processing, the workload increasing while the altitude is decreasing. The workload drops are due to the DDB altitude drop.



4.5.2 PROBE TIME

Summary :

The Probe wake-up can be derived from the “Real Time” (elapsed time since power on) and the S_0 event can be derived from the “Mission Time” (elapsed time since S_0).
The DDB Time (broadcast to the experiments) refer to the elapsed time since PDD firing (T_0).

Event	Expected	Observed
Wake-up time	04:42:20	04:41:19
So detection	09:10:19	09:10:15
To declared		09:10:21

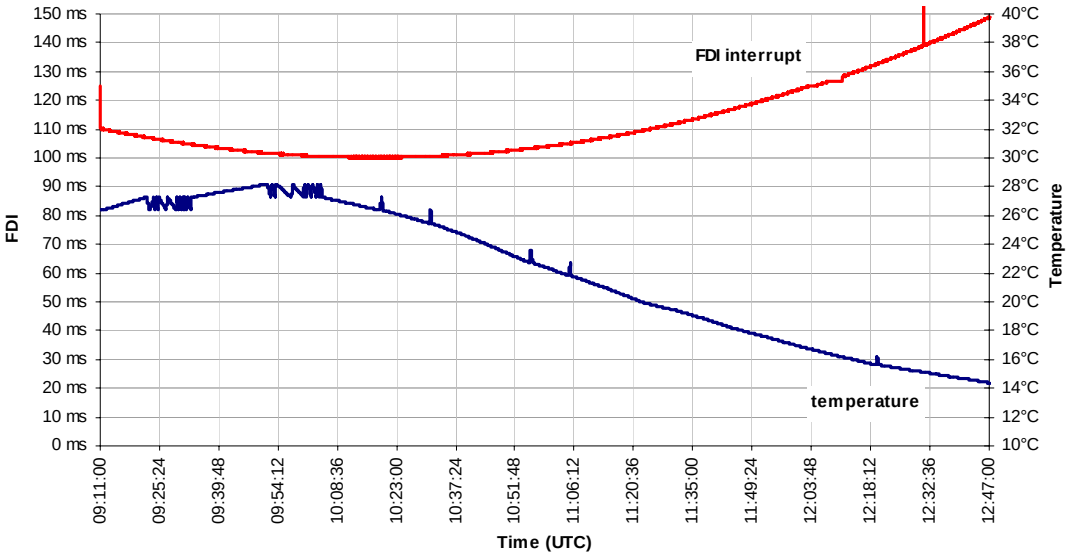
Detailed :

UTC	RTC B	MTC B	DDB time B	Event
04:41:19				**Probe wake-up**
09:10:15	**04:28:41**	**00:00:00**	**04:28:40**	**So detection**
09:10:16	04:28:42	00:00:01	04:28:42	
09:10:17	04:28:43	00:00:02	04:28:42	
09:10:18	04:28:44	00:00:03	04:28:44	
09:10:19	04:28:45	00:00:04	04:28:44	
09:10:20	04:28:46	00:00:05	04:28:46	
09:10:21	**04:28:47**	**00:00:06**	**00:00:00**	**To declared in DDB after 6.6 s**
09:10:22	04:28:48	00:00:07	00:00:01	
09:10:23	04:28:49	00:00:08	00:00:02	
09:10:24	04:28:50	00:00:09	00:00:03	
09:11:01	04:29:28	00:00:47	00:00:40	1st HK3 packet
09:11:17	04:29:44	00:01:03	00:00:56	2d HK3 packet

4.5.3 CDMU CLOCK DRIFT

Summary :

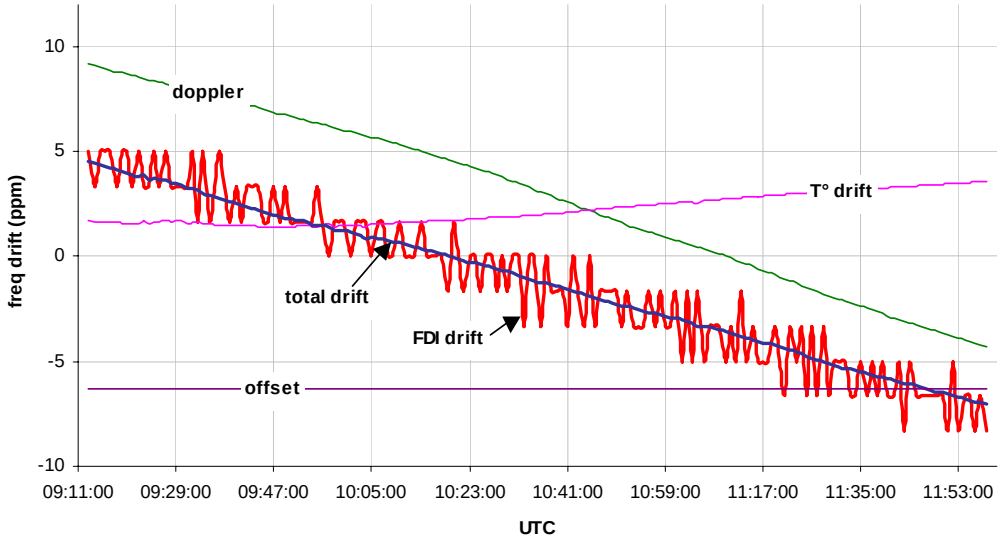
The CDMU clock drift can be observed using the FDI interrupt (Frame synchro marker detection).



The doppler is the main contributor, but the quartz temperature induces also a frequency drift.

$\Delta f_{data} \approx \Delta f_{doppler} + \Delta f_{T°drift} + Offset_{Huygens/Cassini}$

The range acceptable for the receiver is $\pm$ 15 ppm.

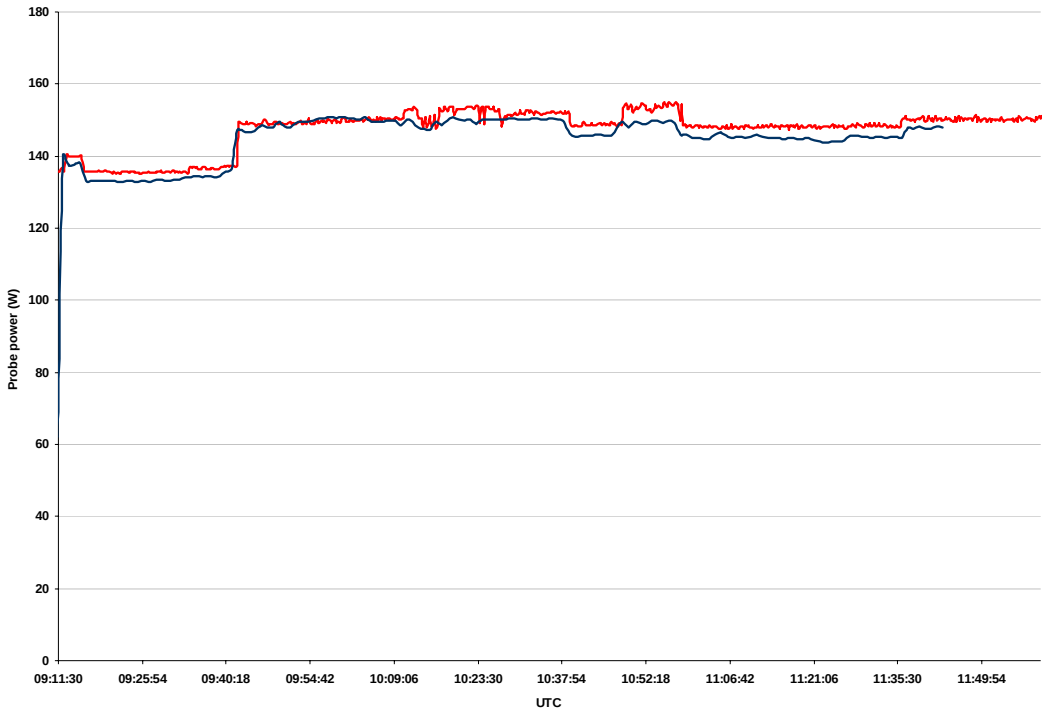


4.6 POWER CONSUMPTION

4.6.1 PROBE

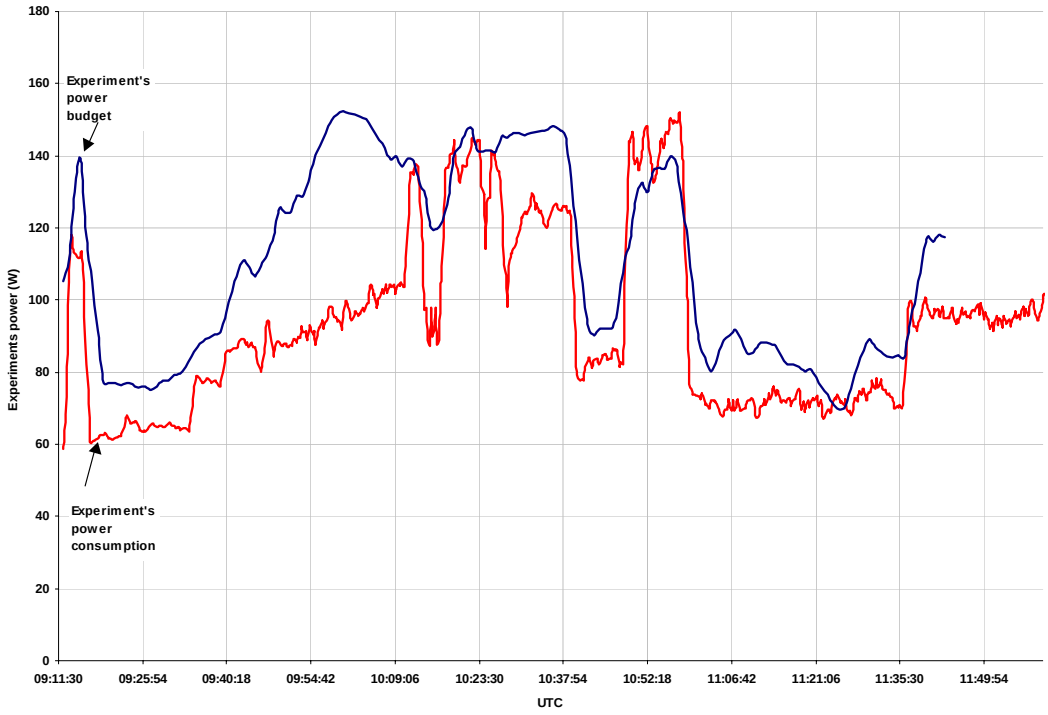
Summary :

The Probe (CDMS+PDRS+EPSS) power consumption is as expected :

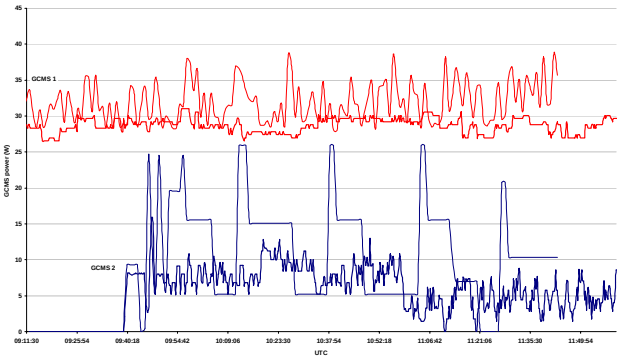


4.6.2 PAYLOAD

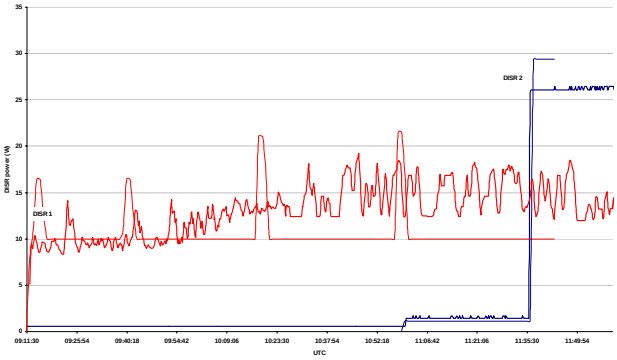
The experiment's power consumption is almost as expected :



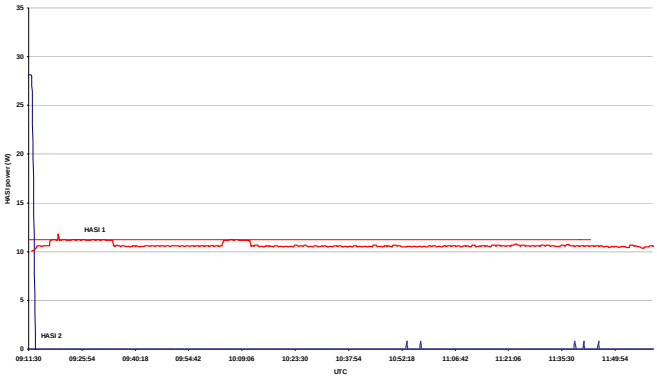
Due to the lost of data from chain A, the power consumption has been estimated from chain B (there are two redundant power buses ored at experiment level). The assumption is that the consumption is balanced on the two buses. This is not true the SSP. The ACP consumption is also different but close to the budget.



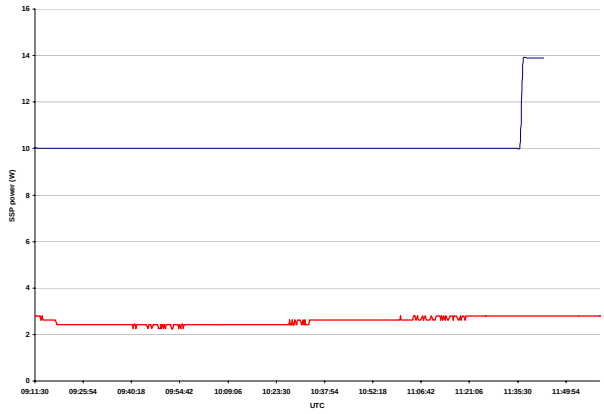
GCMS



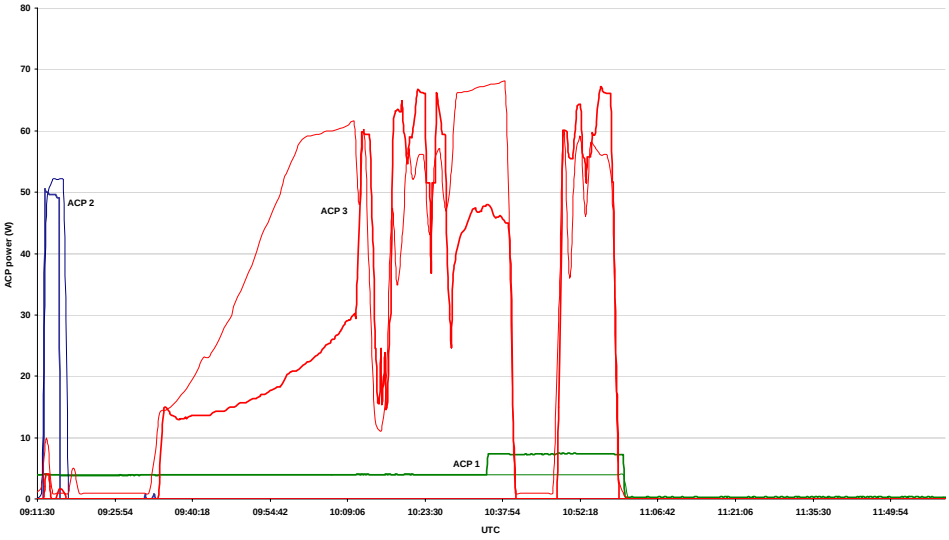
DISR



HASI



SSP



ACP

ANNEX : DEFINITION AND ACRONYMS

ACP	Aerosol Collector and Pyrolyser (experiment)
AGC	Automatic Gain Control
BCM	Back Cover Mechanism
BIU	Cassini Bus Interface Unit
CASU	Central Accelerometer Sensor Unit
CDMS	Command and Data Management Subsystem
CDMU	Command and Data Management Unit
CMD	Command
DDB	Descent Data Broadcast
DISR	Descent Imager and Spectral Radiometer (experiment)
DMA	Direct Memory Access
DTSTART	Dead Time Start
FDI	Frame Data Interface
FSM	Front Shield Mechanism
GCMS	Gas Chromatograph and Mass Spectrometer (experiment)
HASI	Huygens Atmospheric Structure Instrument (experiment)
HPA	High Power Amplifier
HK	Housekeeping
MT	Mission Time
MTT	Mission Timeline Table
MVDA	Mission Visual Data Analysis
NCO	
PDD	Pilot Drive Device
PJM	
POSW	Probe On-board Software
PSA	Probe Support Avionics
RASU	Radial Accelerometer Sensor Unit
RAU	Radar Altimeter Unit (Proximity Sensor)
RTI	Real Time Interrupt (8 Hz clock)
Rx	Receiver
Tx	Transmitter
S_0	Used at system level to denote the software "T_0"
SASW	Support Avionics Software
SSP	Surface Science Package (experiment)
T_0	Entry time in the Titan atmosphere
TAT	Times/Altitudes Table
TC	Telecommand
TM	Telemetry
UTC	Universal Time Code