HUYGENS

TITRE : HUYGENS FLIGHT CHECKOUT F6
TEST REPORT

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RESUME D'AUTEUR

Ce document présente l'évaluation technique de la sonde HUYGENS pendant le sixieme " cruise check out " (F6). F6 s'est déroulé le 28 Juillet 2000.

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1. SCOPE

The present report covers the fifth flight cruise check-out (F6) performed in the frame of the phase F of the HUYGENS Probe

F6 was run at launch + 33.5 months on the 28 th of July 2000. It shall be pointed out that F6 was the first test run after the so called **Probe Relay Test 1** (PRT1) which purpose was to characterize the PSE performance in realistic conditions.

This document aims at analyzing the behavior of the HUYGENS Probe system and subsystems during the test

Note that experiments behavior analysis is not part of this report.

In addition,

- The present analysis is based on the data downlinked in near real time to HPOC/ESOC during F6 through CASSINI High Gain Antenna during a single DSN pass at Goldstone. It was later cross checked with the same data recorded on board CASSINI SSR , and downloaded the day after F6.
- The reference test for comparison is mainly F2, run on the 27th of March 1998 at launch + 5.5 months.
- After some processing all the engineering data plots on the one hand, and dedicated status files on the other hand, were delivered to ALCATEL during the week 27 2000.

2. APPLICABLE DOCUMENTS

The tests have been performed according to the following documents:

- AD01: ESOC F6 sequence
- AD02: Spacecraft Data Operations Handbook (SDOH) : DOPS-SMD-HUY-DB-004, ISSUE 1.0, June 1996.

Reference documents for the present report are:

- RD01: T° Flight Prediction Report
  Doc. n° HUY.MBB.340.AN.0045, Issue 03
- RD02: Thermal model adjustment and recalculation of temperatures
  Doc. n° TN-RIA54-98-0018-A date 07/07/98
- RD03: Huygens Flight checkout F1 & F2 test report
  Doc. n° HUY.AS/c.100 .TR .600
- RD04: Huygens Flight checkout F3 test report
  Doc. n° HUY.AS/c.100 .TR .601
- RD05: Huygens Flight checkout F4 test report
  Doc. n° HUY.AS/c.100 .TR .602
- RD06: Huygens Flight checkout F5 test report
  Doc. n° HUY.AS/c.100 .TR .603

3. CONFIGURATION

3.1. SPACECRAFT CONFIGURATION

- F6 happens 5 months before the CASSINI Jupiter flyby. The -Z axis, ie the High Gain Antenna axis is oriented towards the Earth. At the time of F6 the Sun-Spacecraft-Earth angle is about 10°, leaving Huygens partly illuminated, much less however than during F6. Location of CASSINI at F6 time, and planets/Sun geometry is illustrated in Fig.3.2 & 3.3. S/C orientation is Earth pointed with LGA2/Probe directed in the sunward direction

- The accuracy of the HGA pointing to the Earth, ie CASSINI AACS deadband is +/-2mrad for the X & Y axes and +/-20mrad for the Z axis of CASSINI

- The relative distance to the Sun is ~4.1AU (see Fig 3.1) and to the Earth is ~4.6 AU

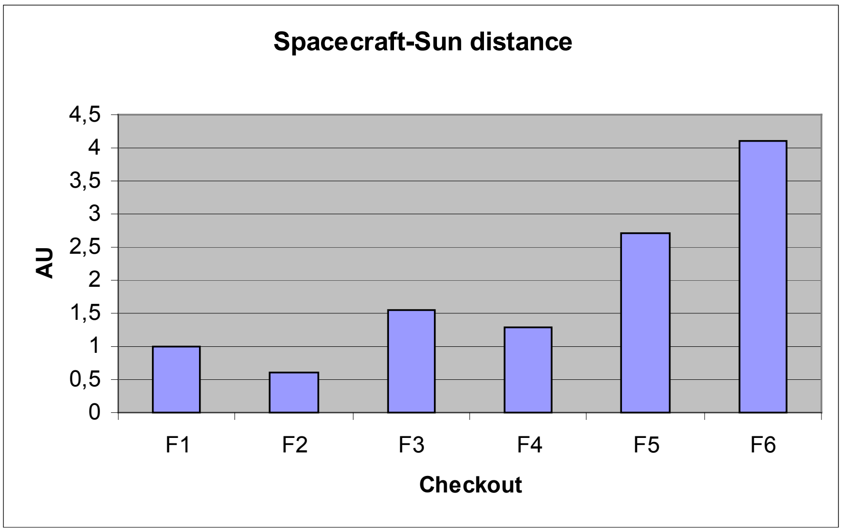


Fig. 3.1: CASSINI – Sun distance

- The CASSINI communication configuration status during F6 is :
  - Prime antenna is the HGA

3.2. RADIO FREQUENCY SUBSYSTEM

TBD

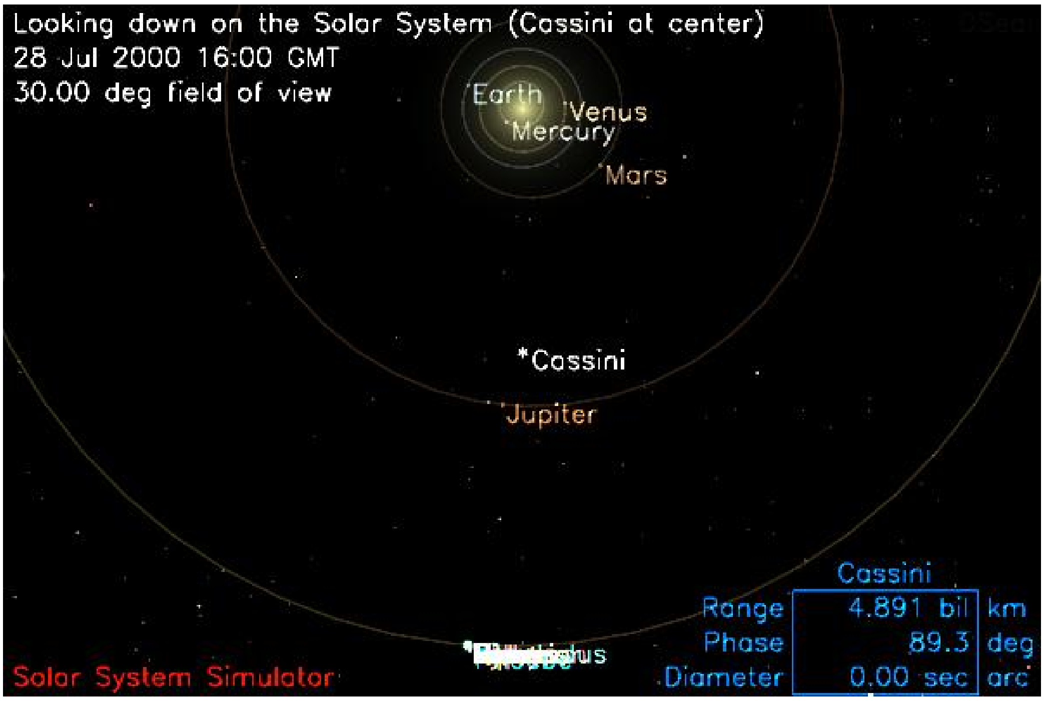


Figure 3.2 : CASSINI position during F6

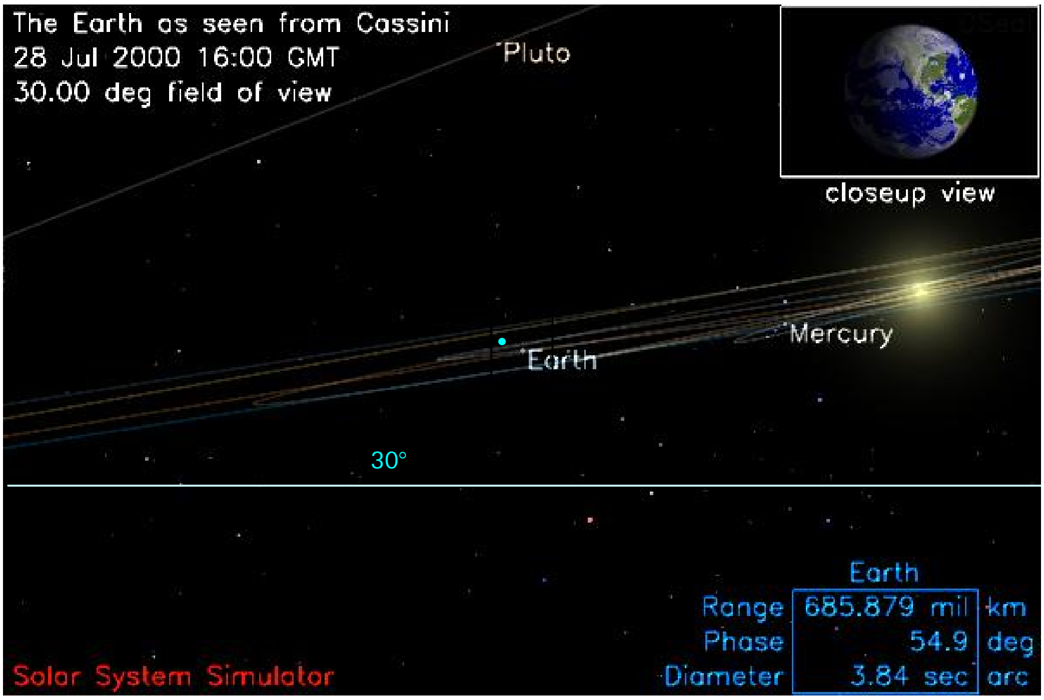


Figure 3.3 : SUN-EARTH position during F6

4. FLIGHT CHECK OUT 6 (F6)

4.1. OPERATIONS

F6 consists in the execution of a so-called Checkout scenario 1a (CO#1a), ie a simulated descent without use of TUSO/RUSO. Compared to the original CO#1 scenario, it also includes :

⇒ a repetition of the " Flight check out " alteration TC to have a better confidence in the TC execution. This mainly intends to ensure that GCMS will not operate its valves in checkout,

⇒ POSW and SASW E²PROMs dumps

⇒ some modifications requested by the Primary Investigators and explicited below in italic letters.

The relevant SASF was loaded on board CASSINI, then executed at a pre-programmed time : execution start was at 16h00 UTC on the 2/2/2000. As already mentioned, CASSINI HGA was pointed towards the Earth, making feasible a real time transmission of the data. Probe telemetry was down linked at a 248 .85kbits /s rate via the DSN station in Goldstone.

The F6 structure is based on:

– PSA activation through Orbiter CDS "power on" TC at S_0-41mn

– Dump SASW A/B EEPROM at S_0-40mn

– Probe wake up by the CASSINI Orbiter via the Solid State Power Switches at S_0-34mn40s

– T_0 simulated by Resume command at S_0 and T_0 detection at S_0+6.375 s

– descent simulation run with Chain A indicated as "valid" : experiments are directed to receive the broadcasted data from Chain A

– RF link on Chain A makes use of TCXO's

– HASI and SSP run a simulated descent *then SSP performs a specific investigation activity on APIS at So+161mn19s for a 42s duration.*

– ACP is in dormant mode during the first 110mn then in "mechanisms check mode" from 140mn to 153mn.

- GCMS runs a simulated descent, with valves disabled by TC's

- DISR runs a "descent", with Spin simulation by TC's. *In addition DISR dumps its EEPROM*

- DUMP POSW A/B EEPROM starting at S0+164mn53sec

The F6 "as run" key events are:

EVENTS	**SEQUENCE TIMING**	**EXECUTION TIME IN UTC**
PSE turn on	S0-0:41:00	2000-210 T16:00:00
PROBE turn on	S0-00:34:40	2000-210 T16:06:20
T0 detection	S0+0:6:375	2000-210 T16:41:06.375
PROBE OFF	S0+2:45:58	2000-210 T19:26:58
PSA's OFF	S0+2:46:52	2000-210 T19:27:52

Checkouts durations are compared in Fig.4.1 hereunder. This shows that F6 was shorter than F3, F4, & F5, and slightly longer than F2, due to the addition of the few additional instruments operations.

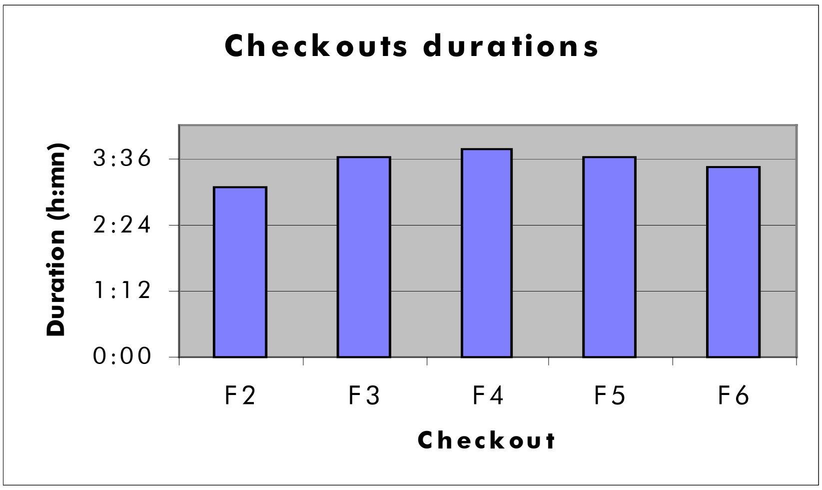


Fig. 4.1: Checkouts durations

4.2. RESULTS

As already mentioned, the analysis is based both on engineering data plots received at ALCATEL Cannes, while the various status of the Probe were made available on the 21/08/00.

Reference for the analysis is **F2**, the previous CO#1a sequence performed on the 27th of March 98, however comparisons are also performed with F4 results (F4 is a CO#1b sequence run on the 14/9/1999) and F5 (F5 is a CO#2 sequence run on the 2/2/2000).

The main outcomes of the evaluation are:

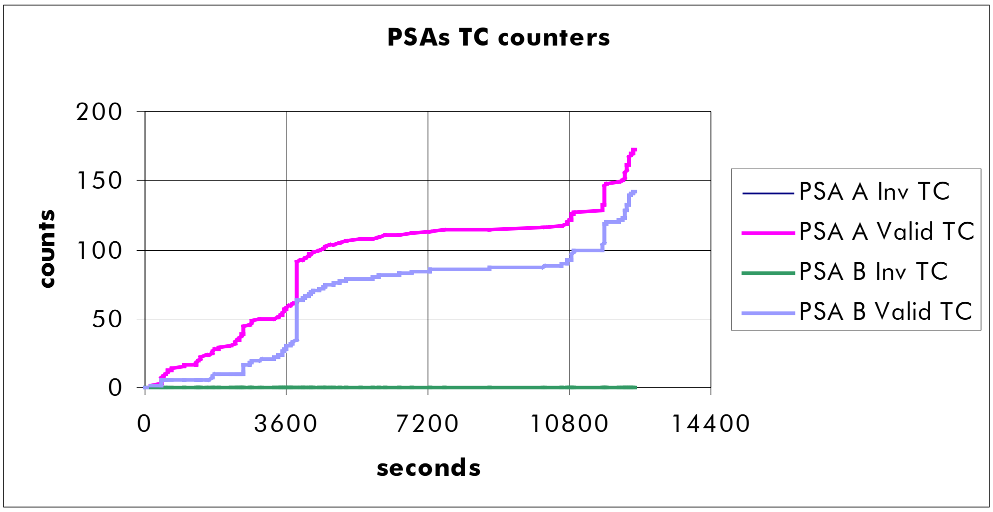
- the timing requested by the scenario are correctly followed by the CDS and all 336 ground TCs are correctly executed for each chain,
- the timeline shows no anomaly (an overview of the sequence is given by the DDB information versus time)
- all the status information was detaily checked and validated from the data retrieved.

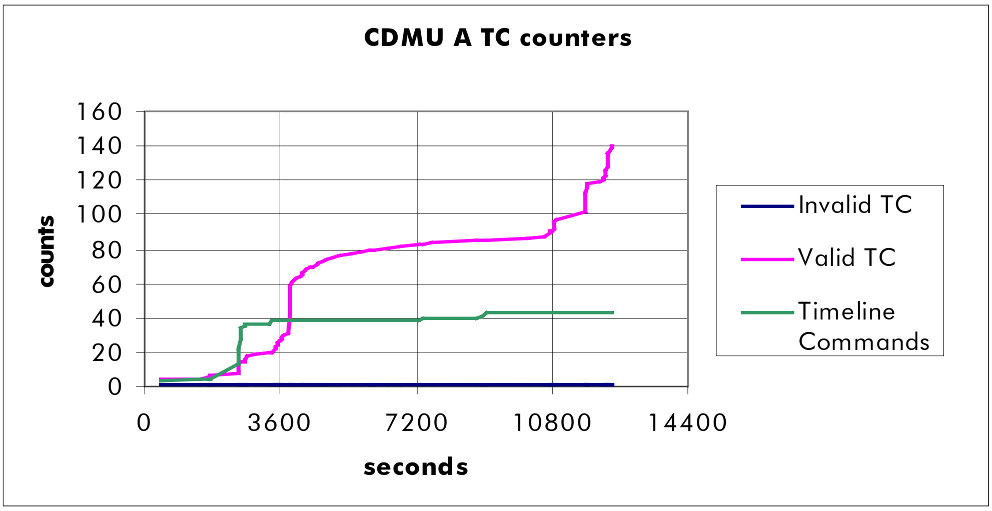
The following presents the analysis of F6, per function.

4.2.1. Telecommanding

This section addresses the Probe System commanding function through the analysis of the reported PSA, CDMU A & B Telecommand counters, and of the reported CDMU's Mission timeline commands counts. This provides a good overview of the execution of the checkout sequence, and of the Mission timeline.

The Figure 4.2 hereafter shows the evolution of the different counters along F6, where the time "0" corresponds to the start of F6 sequence, ie the turn ON of the PSA A & B. In this time scale, S_0 event happens at t=2460s. ; and T0 is detected at t=2466.375s





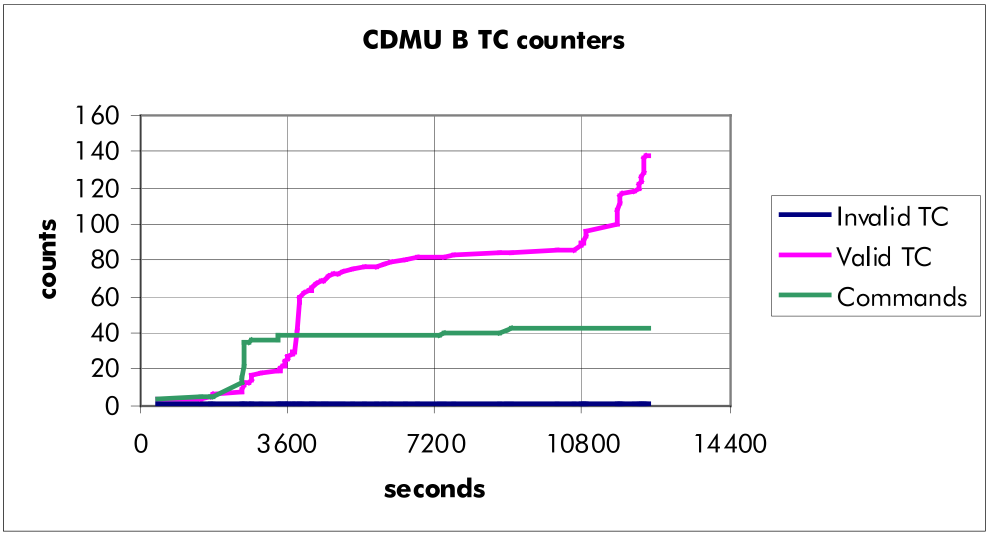


Fig 4.2 : Telecommand counters telemetry

It clearly appears that :

- All ground telecommands have been accepted as valid, both on PSA's and CDMU's side,
- More telecommands have been sent to PSA A, which is due to the numerous commands for switching to basic frequency on chain A,
- Exactly the same number of valid TC have been forwarded to CDMU A & B,
- The evolution of the automatic commands counts, identical for A and B channels is in line with the stored MTT

4.2.2. Telemetry Frames and packets structure

This section deals with the review of the data contained in the telemetry frame and packets headers, especially the various sequence counters evolution with time.

- **PSA Delta Seq. Count**: A Delta value of 1 is nominally reported on both chains.
- **PSA Delta Spacecraft Time**: A Delta value of 1 is nominally reported on both chains.
- **Super Packets Delta Seq. Count**: A Delta value of 1 is nominally reported on both chains
- **Super Packets Master and Virtual Channels Frame Counts**: Periodical reset of the Master channel frame counts on both chains is nominally noticed.
- **Dump Super Packets Delta Seq. Count and Sequence Count and Real Time Counter**: A Delta value of 1 in the sequence count and in the spacecraft time is nominally reported on both chains. Similarly, a monotonous increase of the Dump Super Packets absolute Seq. Count is nominally reported on both and the RT Count on both chains increases and resets when the Probe is OFF.

  Note that spurious increases in the super packets delta counts before Probe turn On time was reported during F5, and a telemetry retrieve problem was suspected (see RD6). This assumption has been confirmed by ESOC and corrected . The anomaly does not reproduce during F6.
- **Probe HK packets Delta Seq. Counts**: a Delta value of 1 is nominally reported on both chains for HK1, 2 & 3. One Delta value of 24 is nominally reported for HK4 on both chains: it corresponds to the reset of this HK packet (which contains Entry Acceleration data), 6.4 mn after $T_{probe\ ON}$. This mechanisms will permit to report the

entry acceleration profile to CASSINI after the telecommunication link establishment, during the real mission.

4.2.3. Telecommunication

Here are addressed the telemetry parameters related to the telecommunication subsystem, its units, and the DWE experiment, as acquired in the Probe System housekeeping.

Main related features are :

- RF link on chain A makes use of TCXO's
- CASSINI HGA is pointed towards the Earth, and the Sun is constantly outside the HGA main lobe.

- **PSA secondary voltages**: PSA 12V, 5V and LNA supply voltage (nominally 12V), are in their nominal range and perfectly stable over the test.

- **RUSO status**: RUSO is not ON during F6 (CO#1a type).

- **TUSO status**: TUSO is turned OFF by command, immediately after its automatic switch ON.

- **TCXOs status**: TM nominally reports TCXO selection on A & B chains,

- **HPA/TX power**: As expected, HPA is OFF, and no power is monitored at TX output.

- **Receivers status**: TM nominally reflects a RSW state of 2 until TXs are turned ON, on both chains..

  As expected ; switch to basic frequency happened successfully at the first attempt for chain A and B ; both of them operating on TCXO.

- **AGC**: The table hereunder evidences the AGC evolution since the first flight checkout. The AGC level for F6 is well in accordance with conclusions reached after the AGC specific test (see RD3) and confirmed by F3, F4 and F5: the very favorable AGC level is explained by the Earth-spacecraft-Sun geometry illustrated in Fig. 3.2 & 3.3, considering that the HGA is pointed towards the Earth.

TEST	AGC A	AGC B
F1	-101 dB+/-0.4 S shape period 85 mn	-100.6 dB +/-0.4 S shape period 85 mn
F2	-104 dB+/-0.5	-106 dB+/-0.4
Off Sun Test	-94.6 dB+/-0.1	-93.3 dB+/-0.1
F3	-98 dB→ -100.5 dB+/-0.4	-97.8 dB →-98.8dB+/-0.4 small amplitude max 99.3 dB
F4	-98 dB +/-1dB S shape period 40 mn	-97 dB +/-1dB S shape period 40 mn
F5	**-93.5 dB +/-0.5dB**	**-93 dB +/-0.5dB**
F6	**-93.8 dB +/-0.5dB**	**-93 dB +/-0.5dB**

- **NCO**: as far as the Probe System is concerned, NCO frequency changes are as expected, both on chain A and chain B, and very similar to F2 (no USO)**.** Also, so called dF/dt parameters on both chains are within the expected range.

4.2.4. Power

- **CASSINI Telemetry** has shown :
  - PSA A average consumption is 25W,
  - PSA B average consumption is 25W , which means a total PSE steady state consumption of 50, identical to F2
  - Probe total average maximum consumption is ~~150W~~.

Both values are well in line with reference test results.

- **Current limiters status and Pyro relays status** have been cross checked with the retrieved telemetry :
  - Nominal Current Limiters status changes during F6 are displayed in Fig 4.3. They are fully in line with the Mission Timeline and F6 sequencing.

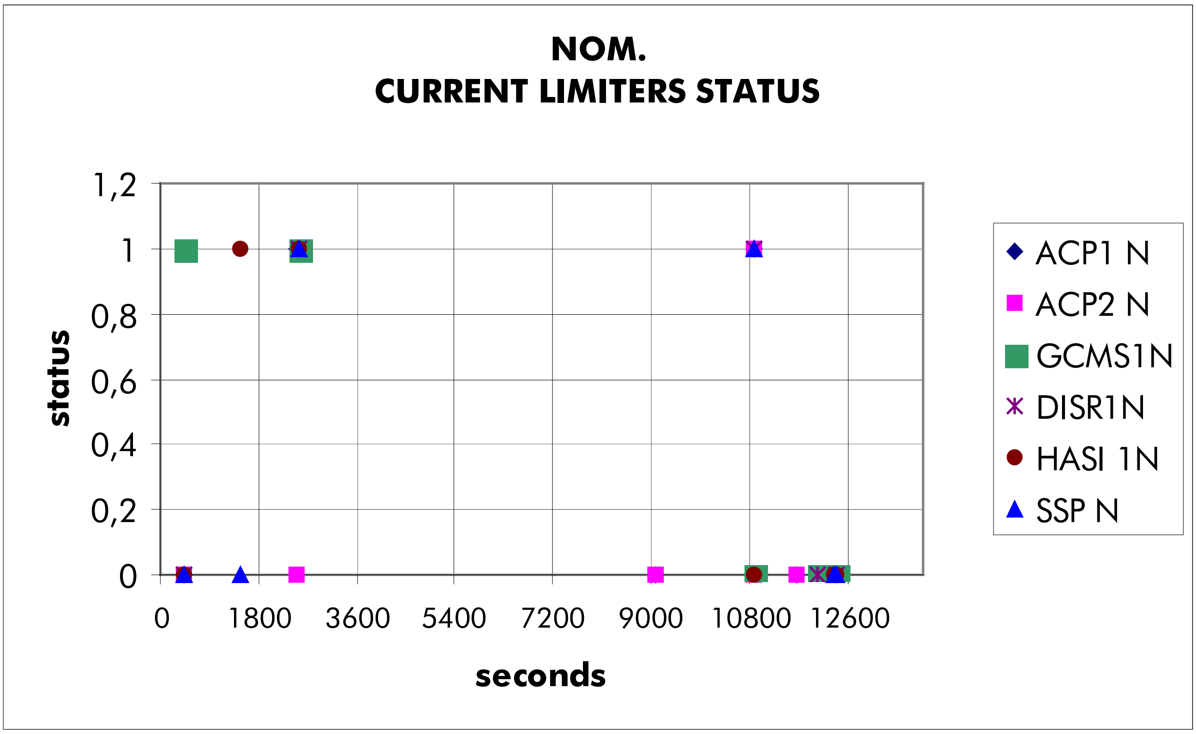
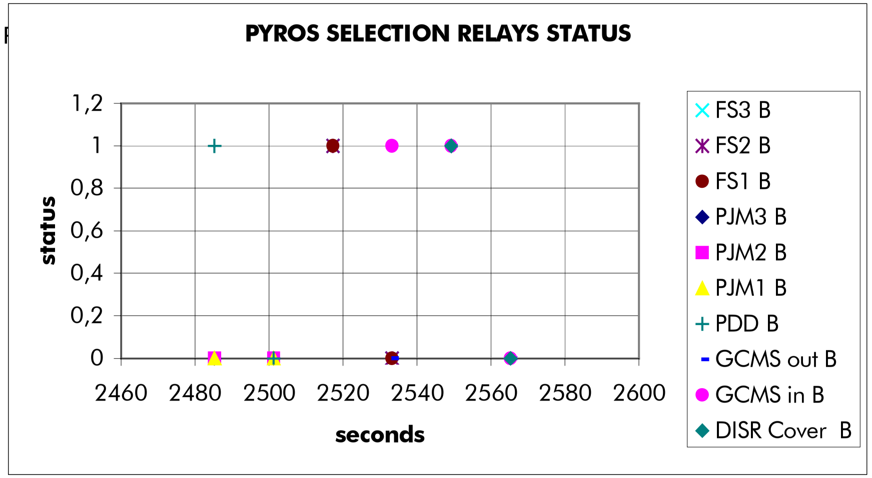
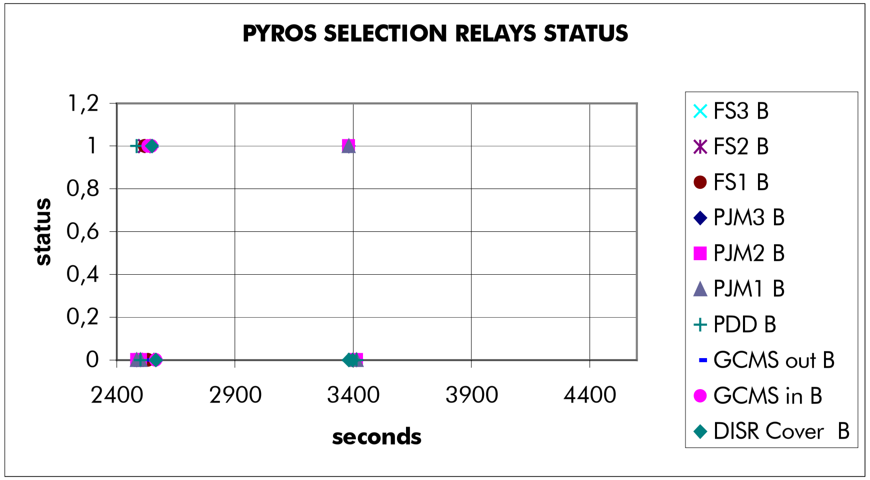
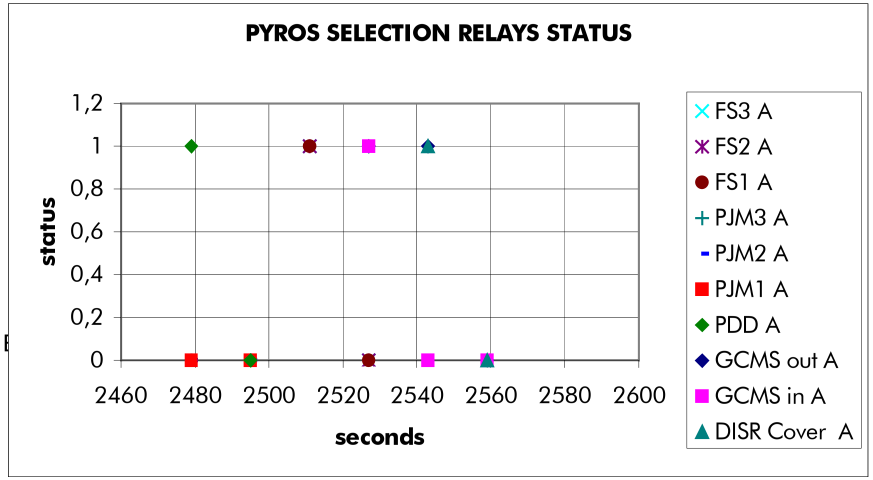


Figure 4.3 : Nominal current limiters status changes along F6 ("0" = start of F6)

- Pyros selection relays status changes during F6 are displayed in Fig 4.4 for both chains, with a zoom around T0. All the nominal and redundant relays are set and reset by each of the chain at the proper time, fully in line with the Mission Timeline and F6 sequencing. It shall be noted that the period of reporting of the pyro selection relay status is 16s.







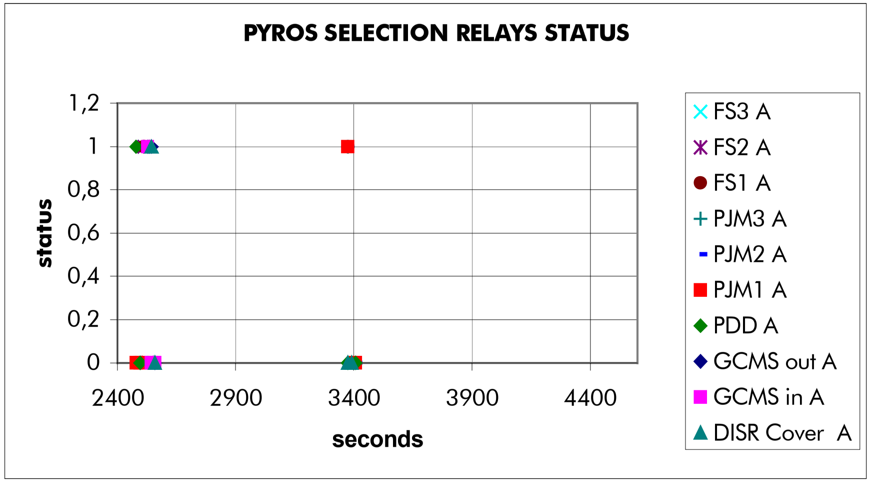


Figure 4.4 : Reported selection relay status changes along F6 (NB : S0 is at t=2460s)

- **Main bus voltage** is 28.09 Volts, as expected.

- **Batteries voltages** telemetry at the end of the test are similar to the telemetry reported during F3.

	F1	F2	F3	F4	F5	F6
battery 1 A	2.93 V	2.28 V	2.00 V	2.6 V	2.00 V	2.28 V
battery 2 A	2.6V	2.28 V	2.00 V	2.28V	2.00 V	1.96 V
battery 3 A	1.3 V	1.30 V	1.00 V	1.30 V	1.00 V	0.98 V
battery 3 B	1.3 V	1.30 V	1.00 V	1.30 V	1.00 V	0.98 V
battery 4 B	2.6 V	2.28 V	2.00 V	2.30 V	2.00 V	1.96 V
battery 5 B	2.28 V	1.96 V	1.63 V	1.96 V	1.63 V	1.63 V

Note that these voltages, as long as batteries are not connected to the PCDU, are not in any way representative of the actual batteries voltages; they reflect the leakage current in the measurement diode which is somewhat proportional to the PCDU temperature.

The lower battery 3 voltage parameter is due to the cross trapping of the relevant telemetry.

- **BDR currents** are in accordance with the operating modes of the Probe System and experiments and identical to the reference test, ie, at different phases of the mission :

	Pre To	To To+110 mn	To+140 mn	To+154 mn	Reference test
BDR1	0.46 A	0.75 A	0.7 A	0.5 A	F2
BDR2	0.43 A	0.69 A	0.65 A	0.45 A	F2
BDR3	0.43 A	0.69 A	0.65 A	0.45 A	F2
BDR4	0.43 A	0.69 A	0.65 A	0.45 A	F2
BDR5	0.46 A	0.75 A	0.7 A	0.5 A	F2

- **Units and Experiments currents** are summarized in the following table. They are in perfect accordance with the reference test and expected behavior.

UNITS	CURRENT	UNITS	CURRENT	Reference test
TX A	0.19 A	**TX B**	0.195 A	F2/F5
TUSO N	0.4 A during 16s0	**TUSO R**	0.4 A during 16s	F2/F5
CDMU A	0.326 A	**CDMU B**	0.337 A	F2/F5
Prox Sensor A	0	**Prox Sensor B**	0	- (unit is OFF)
DISR1 N	0.16 A/peak 0.23 A	**DISR1 R**	0.15 A/peak 0.22 A	F2
DISR2 N	0	**DISR2 R**	0	F2
GCMS1 N	0.25 A in pre To 0.42 A in post To	**GCMS1 R**	0.23 A in pre To 0.4 A in post To	F2
GCMS2 N	0	**GCMS2 R**	0	F2
HASI1 N	0.2 A in post To	**HASI1 R**	0.18 A in post To	F2
HASI2 N	0	**HASI2 R**	0	F2
ACP1 N	0.07 A	**ACP1 R**	0.07 A	F2
ACP2 N	0	**ACP2 R**	0	F2
ACP3 N	Peaks up to 0.30 A	**ACP3 R**	Peaks up to 0.38 A	F2
SSP N	0.32 A	**SSP R**	0.027 A	F2

4.2.5. Data handling

This section deals with the analysis of all the telemetry data related to the CDMS, and to the PSA's data handling fonction.

- **Central Acceleration data**: The reported TM on A and B nominally shows a 0 g value for the accelerometer 2 (parameters 2A, 2B).and 3 (parameters 3A, 3B)

  For the CASU accelerometer 1, a value of 0g is reported on both 1A & 1B TM, with few spurious 1 LSB peaks.

  It shall be underlined that spurious drifts on the accelerometers 1 and 3 telemetry were evidenced during F1, F2, F3 & F4. While the noise peaks reported within F1 and F2 were marginal, the problem got much worse during F3 with noise peaks reaching up to 2 LSBs, then slightly improved during F4.

The situation during F5 was definitely better : only accelerometer 1 TM seldom showed 1LSB peaks. F6 is in line with the measurement observed in during F5.

Tentative explanations were provided in the F3 report describing the noticed noise as possibly coming from a stiction effect at the level of the accelerometers 1 & 3. This is actually not in contradiction with the observed improvement, the stiction being strongly dependent upon the initial conditions of the test, and the entry acceleration parameters shall be kept under a close monitoring

- **Radial Acceleration data**: The reported TM nominally shows a 0 g value.

- **DDB Mission Phase flags**: The telemetry properly reports the mission modes changes, identical to F3 : Flight Checkout Suspended and De-activate modes.

- **DDB F1 & F2 flags status**: T_0 "detection" is correctly reported on both chains through F1 change. F2 nominally reports the TAT use over the whole sequence. Note that T_0 corresponds to the time of pilot chute firing, and **$T_0 = S_0$ +6.375s** where S_0 corresponds to the g-threshold detection by the POSW.

- **DDB Time**: For both chains, it is in line with Probe Real Time before T_0, then with Probe [Mission Time - 6.375s] from T_0 (ie. here from Tp+34mn6.375s to Tp+201mn38s).

- **DDB Altitude** : Nominally set to 320 km until T_0, then follows the Time Altitude Table (TAT) down to "surface" (Proximity Sensor is OFF).

- **DDB Spin** : TM reports permanently 0rpm since Spin is not simulated in CO#2 type sequences.

- **µprocessor Valid** : As expected, analysis of the Probe status shows that both CDMUs have been set as “ valid ” all along F6, giving the experiments the opportunity to listen to the A chain (CO1). Processor Valid evolution along F6 is shown in Fig 4.5 hereafter.

- **MTU** : All three timers registers content, as read by both CDMUs, are reported to be 16#FFFF. These are the expected values when the MTU is turned on, but not programmed, as per F1, F2, F3 & F4.

- **EEPROM’s** : As for F3, a complete CDMUs EEPROM (16kW) and PSA EEPROM (8kW) dump was performed, and the content was compared to the expected one, ie. in the present case, the memory contents as dumped during F4. No difference between F4 and F6 was noticed for all 4 memory banks, showing a good immunity of the CDMUs and PSA’s EEPROM chips to Single Event Upsets in unbiased conditions.

– **Processor boards** : no anomaly in the PSA's and CDMU's init was noticed. In addition, no double nor single RAM (CDMU's o PSA's) error was flagged by the EDAC circuitry all over F6 duration.

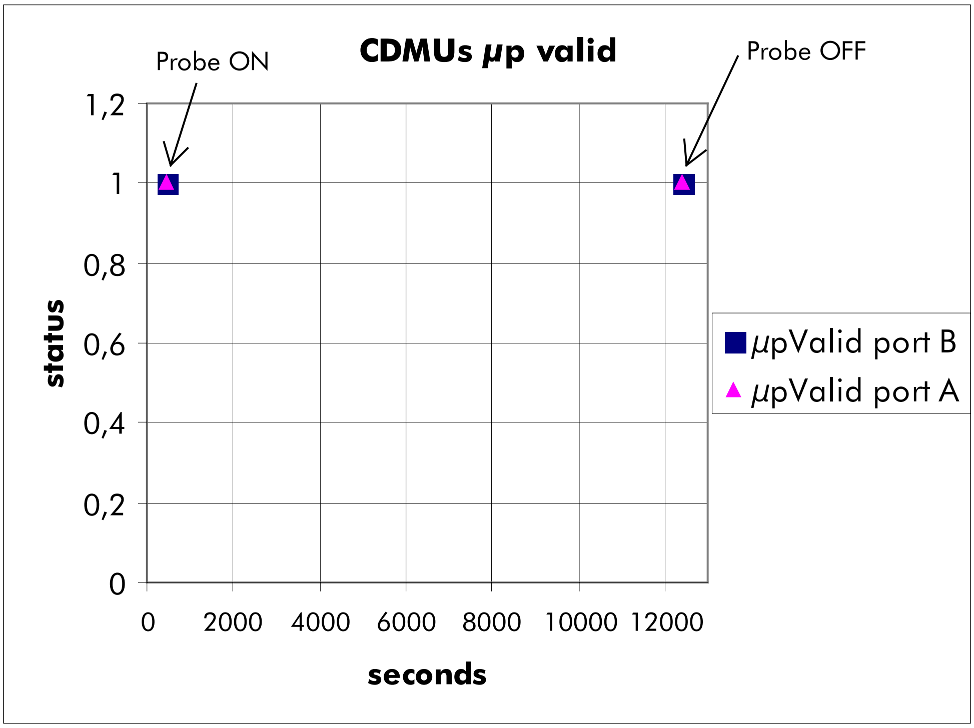


Fig 4.5 : µp Valid changes along F6 (S_0 is at t=2460s)

– **Reference voltages** : this telemetry provides highly accurate information on the current performance of the CDMUs acquisition chain in view to possibly adjust the analog parameters calibration curves, and especially the Entry Accelerometers ones, on board. There are 3 stabilised reference voltages :

- 4.54V, and
- 300mV and
- 500mV

the later ones being set to be close to the voltage corresponding to the S_0 g-threshold, ie. 522mV.

The Fig 4.6 and 4.7 hereafter show the evolution over F6 of the stabilised voltages as acquired by the CDMU's. The telemetry of the CDMU's 5V supply voltage is also displayed. This clearly demonstrate the very good operation of the Analog acquisition chain. Also, no degradation from launch time is evidenced.

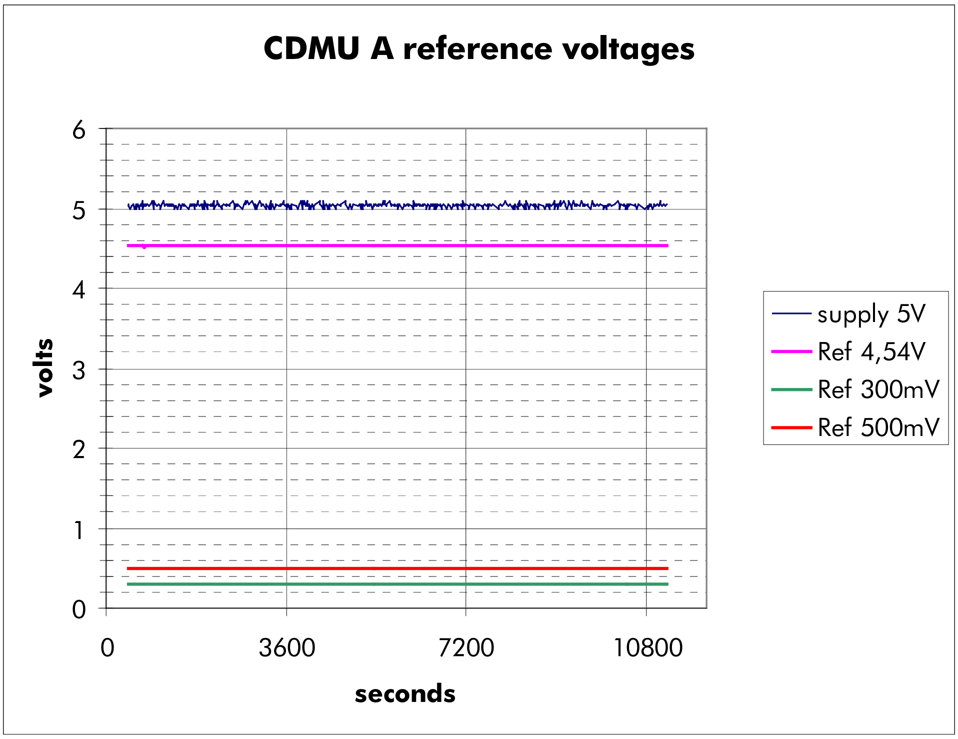


Fig 4.6 : CDMU A Voltages (5V is not stabilized)

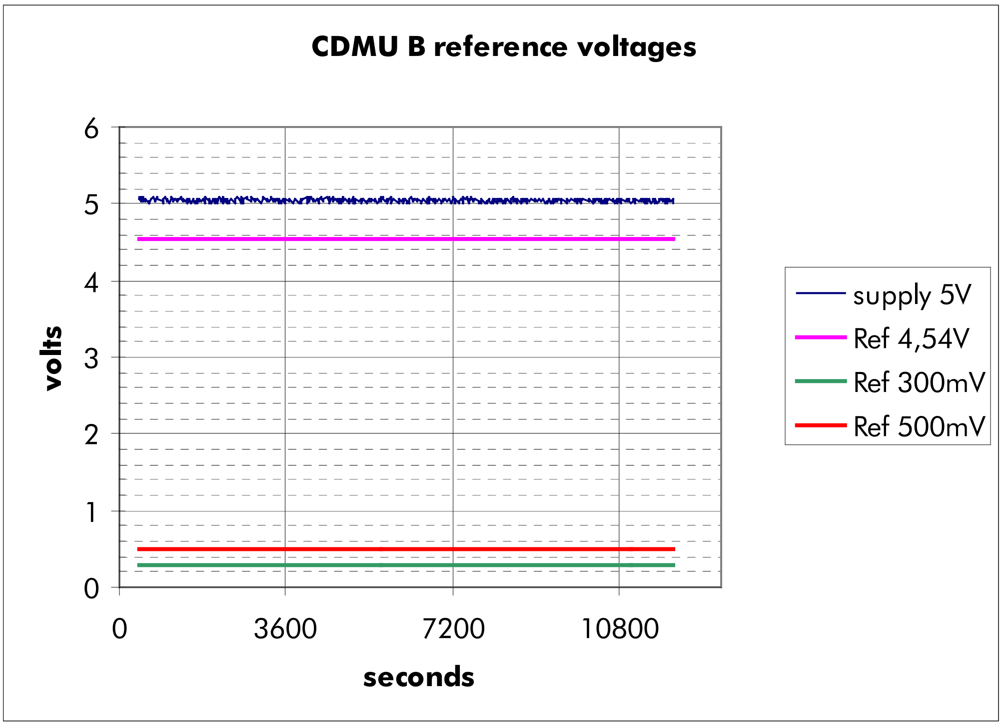


Fig 4.7 : CDMU B Voltages (5V is not stabilized)

4.2.6. On board software

4.2.6.1. SASW

This paragraph addresses the telemetry related to the SASW operation.

- **High Stack Water Mark:** This parameter aims at providing data on the stack usage by the SASW. It reports the 16bits address of the top of the stack, which shall be lower than the Stack base address, i.e. 16#EFFF. Value reported during F6, 10#7068 is identical to F1, F2, F3, F4 & F5 tests data.

- **SASW CUT Processing Time**: It reflects the processor load for each CUT. As expected, and as per F1, F2, F3 & F4, processing time ranges from 16ms to 27ms, representing a nominal PSA data handling processor load of about 20 %.

- **DT Start/End Time, DT Start EXEC**: The DTStart parameter provides the time within the CUT when the Dead Time Start signal is received by the SASW. It shall be <120ms. DTEnd parameter provides the time within the CUT when the DTStart interrupt processing stops. The interrupt processing duration is given by the **DTStart EXEC** parameter.

  During F6, on both chains, **DTStart** nominally happens 18.7ms after the CUT start; processing duration is in average 1.4ms, in line with the reference test results.

- **FDI Start/End, FDI EXEC:** The **FDIStart** signal provides the time when a Probe frame is received. **FDIEnd** provides the time when the FDI is serviced, while **FDI EXEC** simply indicates the duration of the interrupt servicing.

  It shall be noticed that the **FDIStart** signal monotonously increases because of the Probe (CDMU's) TM clock drift w.r.t. CASSINI RTI.

  The Fig.4.8 shows the drift of the parameter, and the derived drift of each CDMU clock with respect to CASSINI RTI.

  The Fig. 4.9 shows the clocks drifts as a function of the temperature measured at CDMU DC/DC converter level over F6, and compares these drifts to F3, F4 and F5 ones. This demonstrates that the TM clock on board the CDMU's is well within its stability requirement of 60ppm overall, and has not degraded from F3.

  Processing duration, given by **FDI EXEC** parameter is in average 0.8ms, in line with the reference tests results.

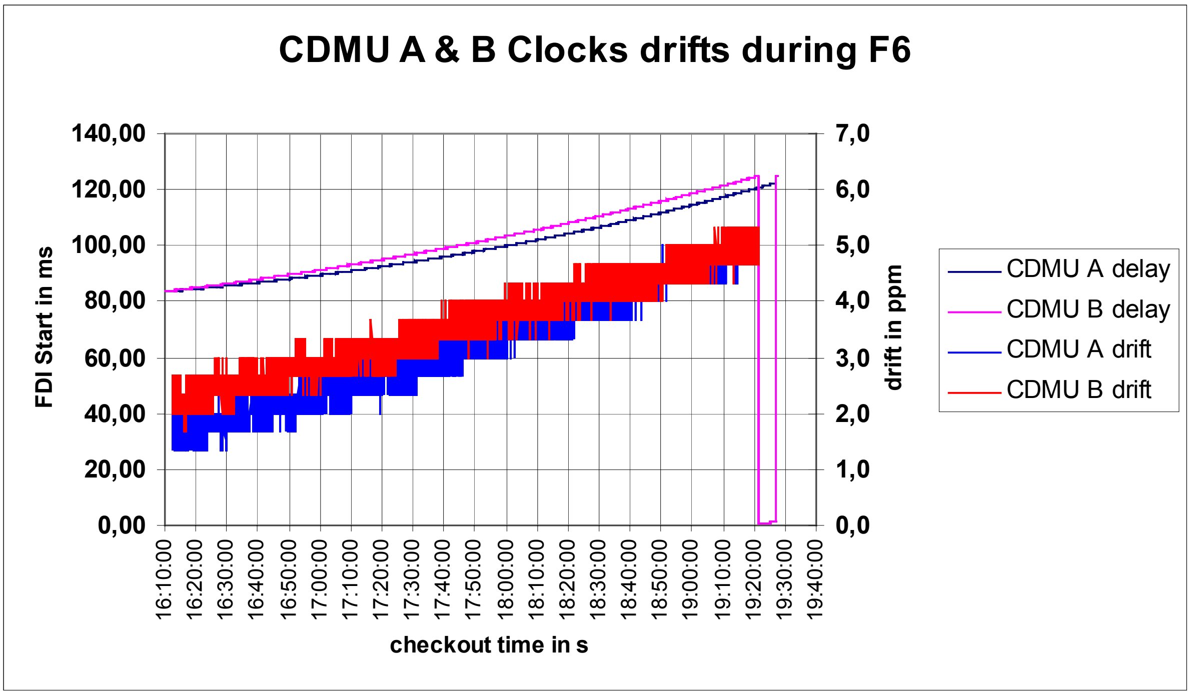


Fig 4.8 : CDMU A & B TM clock drift over F6

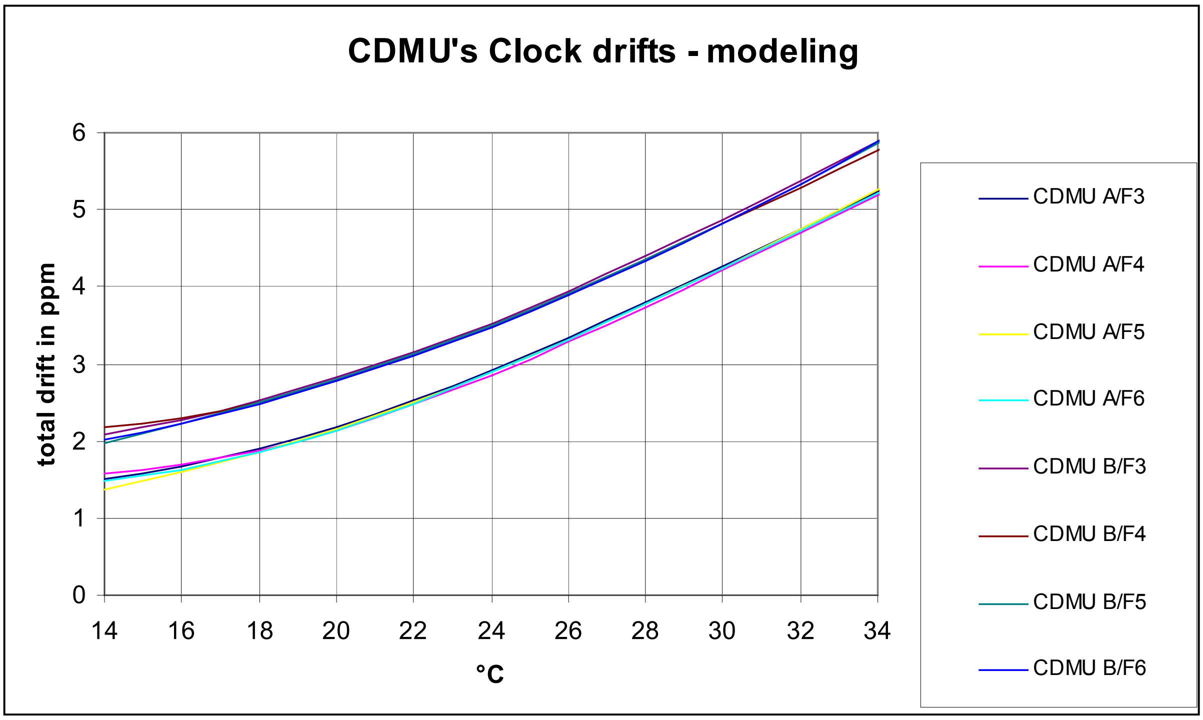


Fig 4.9 : CDMU A & B TM clock drift over temperature

- **DMA Start/End, DMA EXEC:** The DMAStart signal provides the time when a Direct Memory Access interrupt is received. **DMAEnd** provides the time when the DMA interrupt is serviced, while **DMA EXEC** indicates the duration of the interrupt servicing.

  The evolution of the telemetry related to DMA interrupt is quite similar to FDI related telemetry, with the same comments.

  Duration of the interrupt servicing is, in average, 1.4ms, in line with the reference tests results.

As a conclusion, we have [**DTStart EXEC + FDI EXEC + DMA EXEC** = 3.6ms], and the constraint for a correct software operation being [**DTStart EXEC + FDI EXEC + DMA EXEC**< 4.5ms] is fulfilled.

4.2.6.2. POSW

This paragraph addresses the telemetry specifically related to the POSW operation.

- **High Stack Water Mark:** This parameter aims at providing data on the stack usage by the POSW. It reports the 16 bits address of the top of the stack, which shall be lower than the Stack base address, i.e. 16#EFFF. Value reported during F6, 10#7425 is well in line with reference test data.

- **POSW CUT Processing Time**: It reflects the processor load for each CUT. The reported value is a worst case value over the 128 CUT major acquisition cycle and is actually the residual value of the CDMU's μprocessor timer B at the end of the processing time.

  As expected, Processing time ranges from 56 ms to 60 ms, representing a nominal CDMU data handling processor load of about 47 % max. A slow increase of the processor load from T_0 time can be noticed; it reflects the fact that the MTT processing time is correlated to the place of the event in the timeline, therefore the current Mission Time.

  In total, the POSW processing time during F6 is very much comparable to F2, and denotes a correct operation of the software over the whole checkout.

4.2.7. Thermal

This section discusses telemetry measurements related to the THSS : Probe and PSE temperatures in Probe housekeeping, including units internal T°, plus Probe and PSE temperatures in CASSINI housekeeping.

Temperatures values permanently acquired by CASSINI are summarized in the table hereafter:

IDENTIFICATION	F6 MEASURED RANGE INIT T° → END T°	F5 MEASURED RANGE INIT T° → END T°	F4 MEASURED RANGE INIT T° → END T°	F3 MEASURED RANGE INIT T° → END T°	F2 MEASURED RANGE INIT T° → END T°
MIMI elec T°	15°C → 19°C	15°C → 19°C	22°C → 22°C	16° C → 19° C	18°C → 22°C
Probe T° 1	10°C → 32°C	10°C → 32°C	12°C → 35°C	12° C → 33° C	15°C → 30°C
Probe T° 2	10°C → 32°C	10°C → 32°C	12°C → 34°C	12° C → 33° C	15°C → 30°C
LNA A Temp	-10°C → -5°C	-10°C → -5°C	-4.7°C → 0.5°C	-8° C → -2.5° C	-1° C → 1°C
LNA B Temp	-10°C → -5°C	-10°C → -5°C	-5°C → 0.5°C	-8° C → -2.5° C	0° C → 2°C
SEPS Temp 1	-51°C → -50°C	-51°C → -50°C	-50.2°C → -49.5°C	-53° C→ -56° C	-45°C → -43° C
SEPS Temp 2	-50.5°C → -48.5°C	-50.5°C → -48.5°C	-50.2°C → -49.5°C	-52° C → -56° C	-45°C → -42° C
SEPS Temp 3	-50.5°C → -49.5°C	-50.5°C → -49.5°C	-52.5°C → -52.8°C	-56° C → -56° C	-49°C → -47°C
SEPS Temp 4	-54.1°C → -52.7°C	-54.1°C → -52.7°C	-54.8°C → -54.8°C	-56° C → -56° C	-52°C → -50°C

Temperatures values, in °C, acquired by the HUYGENS Probe are summarized in the tables hereafter:

a. Descent module External units:

TM IDENTIFICATION	T° SENSOR	F6 MEASUREMENTS (28/07/2001)			F5 MEASUREMENTS (2/02/2000)			F4 MEASUREMENTS (15/09/99)			F3 MEASUREMENTS (22/12/98)		
	Location	T init	T end	**Delta**	T init	T end	**Delta**	T init	T end	**Delta**	T init	T end	**Delta**
1A	SEPS A	-48.6	-48.6	**0**	-47.7	-47.7	**0**	-47.7	-47.7	**0**	-50	-50	**0**
2B	SEPS A	-48.6	-48.6	**0**	-47.7	-47.7	**0**	-47.7	-47.7	**0**	-49.5	-49.5	**0**
1B	SEPS B	-50.9	-50.9	**0**	-48.6	-48.6	**0**	-49.5	-49.5	**0**	-53.5	-53.5	**0**
2A	SEPS C	-52.6	-52.6	**0**	-51	-50	**1**	-51.7	-51.7	**0**	-54.3	-54.3	**0**
3A	PJM A	-26.5	-25.9	**0.6**	-27	-26.3	**0.7**	-26	-25.3	**0.7**	-28	-27.2	**0.8**
3B	PJM B	-24.4	-24.9	**0.5**	-25	-24.3	**0.7**	-24	-23.4	**0.6**	-25.7	-25.3	**0.4**
4A	PJM C	-25.8	-25.3	**0.5**	-26	-25.6	**0.4**	-25	-24.7	**0.3**	-26.9	-26.5	**0.4**
4B	PDD	-22.2	-21.9	**0.5**	-23	-22.5	**0.5**	-21.5	-21.3	**0.2**	-23.2	-23.1	**0.1**

b. Descent Module Internal units

TM IDENTIFICATION	Sensor Location	F6 MEASUREMENTS (28/07/2000			F5 MEASUREMENTS (2/02/2000)			F4 MEASUREMENTS (15/09/99)			F3 MEASUREMENTS (22/12/1998)		
8A	PCDU	11.3	32.5	**21.2**	10	31.3	**21.3**	12	33.7		10.8	31.2	**20.4**
5A	BATT 1A	15.5	20.9	**5.4**	14	8.8	**4.8**	16.5	21.8	**5.3**	15	19.4	**4.4**
8B	BATT 1B	14	20.9	**6.9**	12	18.8	**6.8**	16.5	21.8	**5.3**	13.1	19.4	**6.3**
6B	BATT 2A	12	22.7	**10.7**	10.5	21.8	**11.3**	13.1	24.5	**11.4**	11.2	22.7	**11.5**
7B	BATT 3A	15	20	**5**	14	18.8	**4.8**	14.3	21.8	**7.5**	15	19.4	**4.4**
6A	BATT 3B	11.3	20	**8.7**	10	18.8	**8.8**	12.5	21.8	**9.3**	10.8	19.4	**8.6**
5B	BATT 4B	15	21.8	**6.8**	14	19.4	**5.4**	15.7	21.7	**6**	14.4	20	**5.6**
7A	BATT 5A	15.3	21.8	**6.5**	14	20.	**6**	16.5	22.7	**6.2**	15	20.9	**5.9**
9A	TX A	13.7	30	**16.3**	12	29.1	**17.1**	14	32.5	**18.5**	13	30	**17**
9B	TX B	13.7	28.2	**15.5**	12	26.4	**14.4**	14	29.1	**15.1**	13	24.3	**11.3**
10A	GCMS	14	28.1	**14.1**	12	27.3	**15.3**	14.5	29.1	**14.4**	13	27	**14**
10B	TUSO	12	25.5	**13.5**	10	33.7	**23.7**	12.5	36.2	**23.7**	11	35	**24**
11A	DISR I/F	-25.4	-25.3	**0.1**	-25.6	-25.6	**0**	-25.2	-26.6	**0.8**	23.4	-26.6	**0.6**
11B	DISR SH	2	7.7	**5.5**	0	5.4	**5.4**	2.5	5.9	**6.1**	1	5.9	**4.9**
12A	FOAM int	8	22.7	**14.7**	7	22.7	**15.7**	9.5	25.4	**15.9**		23.6	**15.6**
12B	CONE (foam ext)	-18.3	-16.1	**2.2**	-19	-16.7	**2.3**	-17.5	-15.2	**2.3**	-19.5	-17.1	**2.4**

c. Probe units internal T° reported through the Probe TM are summarized in the table hereafter:

IDENTIFICATION	**F6 MEASURED RANGE** **INIT T° → END T°**	**F5 MEASURED RANGE** **INIT T° → END T°**	**F4 MEASURED RANGE** **INIT T° → END T°**	**F3 MEASURED RANGE** **INIT T° → END T°**
RUSO Lamp	101.7° C → 101.7° C	112.5° C → 112.5° C	112.5° C → 112.5° C	113° C → 113° C
RUSO resonator	64.4° C → 64.4° C	75° C → 75° C	75° C → 75° C	75° C → 75° C
RUSO crystal	64.4° C → 64.4° C	72° C → 73° C	72° C → 73° C	72° C → 73° C
TUSO Lamp	101.7° C → 101.7° C	112.5° C → 112.5° C	112.5° C → 112.5° C	112.5° C → 112.5° C
TUSO resonator	64.4° C → 64.4° C	76.5° C → 76.5° C	76.5° C → 76.5° C	76.5° C → 76.5° C
TUSO crystal	64.4° C → 64.4° C	74° C → 75° C	74° C → 75° C	74° C → 75° C
PSA A Temp	19° C → 37.3° C	16.5° C → 36.4° C	22° C → 40° C	18° C → 37.3° C
PSA B Temp	19° C → 37.3° C	16.5° C → 36.4° C	22° C → 40° C	18° C → 36.4° C
Tx A HPA	13° C → 33.2° C	13° C → 30.4° C	14° C → 33.3° C	13° C → 31.6° C
Tx B HPA	13° C → 30° C	13° C → 28° C	14° C → 31.2° C	13° C → 28.8° C
CDMU A DC/DC 1	12° C → 33.7° C	10° C → 33.7° C	13° C → 37.5° C	12° C → 35° C
CDMU A DC/DC 2	12° C → 31.25° C	10° C → 31.2° C	13° C → 33.7° C	12° C → 31.3° C
CDMU B DC/DC 1	11.5° C → 31.25° C	10° C → 30° C	12° C → 33.7° C	11° C → 31.3° C
CDMU B DC/DC 2	11.5° C → 29.1° C	10° C → 28.2° C	12° C → 30° C	11° C → 29° C

Conclusion:

The initial steady state temperatures is in general mostly related to the Sun to Spacecraft distance illustrated in Fig. 3.1 but also to the Sun-Spacecraft-Earth angle (CASSINI HGA points towards the Earth) illustrated in Fig 3.3. Considering that the distance to Sun has significantly increased from F5, and that the Sun-Spacecraft-Earth angle has decreased, one would have expected at a first order, a slight decrease of the initial Probe internal temperatures. They are on the contrary slightly warmer than during F5, which may be explained by light trapping effects in between CASSINI and HUYGENS. This is reflected in most of the measured temperatures, with the delta ranges presented below :

	F6-F5	F5-F4	F4-F3
Average delta initial T°	+1.5°C	-2°C to –4°C	+1°C

However, temperatures of some external units (eg. SEPS) have, nominally, slightly decreased w.r.t. to F5, due to different Sun Exposure compared to the Probe body.

The temperatures trends are in accordance with RD02, computed after the model adjustment in July 98 (RD01).

The trends, and the ranges, are in addition fully in line with F5, F4, F3 & F2 measurements considering the respective checkouts durations (see Fig 4.1).

The overall Probe System thermal behavior is therefore considered as nominal.

4.2.8. Experiments status word

The evolution of the Status Word for each instrument, is similar to its evolution during F2, used as the reference test.

Experiments detailed behavior analysis shall be found in the PI's F6 test reports : no anomaly related to the Probe System operation has been notified.

5. CASSINI INSTRUMENTS CHECK OUT (ICO)

This chapter generally deals with the review of the technical issues raised in the F5 to F6 review time frame, related to CASSINI, and especially CASSINI experiments operations which have or may have an impact on the Huygens Probe System.

Belonging to that category, a statement was requested on the possibility to maintain nominally 6 of the CASSINI instruments in “ ON ” but “ sleep ” mode condition during future Probe Checkouts. EMC and 1553 Orbiter Data Bus issues have mainly been addressed via the analysis of documentation provided by JPL and dealing with :

- 1553 Bus muting
- EMC measurements recorded during “ quiet test ” on ground.

As a result, it was stated (see appendix 1), that :

- the mute mode proposed to be used to prevent data generation from CASSINI instruments during Probe Checkouts was fully satisfying HUYGENS request.
- the EMC results from ground testing were not considered to properly cover the conditions planned to be exercised in flight.

As a conclusion, a dedicated flight test has been proposed to assess the CASSINI instruments sleep mode impact on a “ dummy ” Probe Checkout. The detailed implementation of this test is currently under investigation.

6. CONCLUSION

The sixth Cruise Check out was completed on the 28th July 2000, before the CASSINI Jupiter Flyby activities, and at a distance from the Sun of ~4.1AU and from the Earth of ~4.6AU.

ALL THE HUYGENS SUB-SYSTEMS OPERATED NOMINALLY.

However, one still unexplained behavior, evidenced in the previous checkouts, related to the noise level on CASU accelerometers 1 and 3, remained basically unchanged from F5, i.e. fully acceptable from a system point of view. The issue however must be kept opened, and the corresponding TM parameters still need to be carefully monitored.

The RF link between Probe and PSA was excellent, with an AGC signal in accordance with the expected value, without any Sun interference at CASSINI HGA input. The RF link with ground through the CASSINI HGA was nominal without loss of any packet and data.

This good quality of the overall HUYGENS to ground data path is confirmed by ESOC Reed Solomon analysis (see RD 06) which, except during transitions, shows that no Super Packet was rejected, while no correction was performed over a total of 24007 received Super Packets.

To conclude, the HUYGENS Probe System status after the PRT 1 (Probe Relay Test 1), and before the PRT 2 was very good.

APPENDIX 1 : assessment of HUYGENS Probe Compliance with CASSINI instruments in "Sleep mode"

In response to the JPL/ESA request to assess the potential impacts of keeping the Orbiter experiments in a non " OFF " state during the Huygens checkout, here is Alcatel position :

After a brief review, 2 main areas related to the Huygens Probe operation have been identified to be potentially affected by leaving the CASSINI fields and particles instruments (Mimi, CAP, MAG, RPWS, CDA) in sleep mode during the Probe checkouts, instead of turning them off, as initially understood. These are :

1- the Electromagnetic emission of CASSINI compared to the Huygens Probe susceptibility

2- the traffic on the 1553 data bus.

It shall first be recalled that the discussed mode of operation, ie Probe checkout with some CASSINI experiments "ON", was never considered as baseline in the course of the development and test of the Huygens Probe, and therefore no ground test at CASSINI level has ever been performed in such a configuration.

Consequently, the assessment on the Probe compatibility can only be done by analysis or extrapolation from available test data.

1- Compatibility with Electromagnetic emission by CASSINI

Results from Huygens system EMC tests :

Tests were conducted on the Huygens flight model with the following outcomes :

Conducted tests

Compatibility with IRD was checked for both power and signal lines, and no major non conformance was raised. Especially the susceptibility tests did not exhibit any non conformance.

Radiated testing

Tests were performed in open and closed (but without the back cover and front shield) configurations. RE tests have shown a perfect Huygens/CASSINI compatibility, considering IRD derived levels. As far as RS tests are concerned (which are the tests of particular interest here) only auto-compatibility tests were run (eg. Huygens RS against Huygens RE) with margins in excess of 37dB.

Results from CASSINI system EMC tests :

The present statements result from the review of the Kuberry & Narvaez document "CASSINI systel level EMC test : Summary report for HUYGENS Probe Interface Requirements".

Conducted tests

Measurements were only performed on the power bus at Huygens during Probe EM integration. CASSINI emissions were compliant. No measurement at Huygens were possible at the time of the Science Quiet test; however measurements performed at the S/C side were OK.

Radiated testing

A test was run to measure CASSINI emission during the Science Quiet Test, but only Huygens STPM was installed. During this test, each CASSINI instrument was cycled into its "noisy" state, and sweeps were recorded. From the corresponding figures, it remains however very hard to deduce any compatibility with Huygens.

On the contrary, during Huygens radiated emission tests on CASSINI, both Probe and PSE (EMs) were powered; CASSINI was in a quiescent mode, and its science instruments were in sleep/listen mode. This is apparently the only case where the configuration was roughly similar to the one planned for the subsequent Probe Checkouts in flight. Of course no figure at Huygens side is available (the test aimed at measuring Huygens emission, not susceptibility), but it seems the test has somewhat demonstrated a functional compatibility of Huygens with the planned CASSINI/instrument configuration, at least in term of "no damage".

Conclusion :

Although the available EMC data does not definitely permit to formally state the compatibility of Huygens operation in checkout with some CASSINI instruments in sleep mode, some good indications exist that the Probe checkout won't be affected ; in any case, the possible EMC interference won't create any damage.

2- Compatibility with operations on the 1553 data bus

Leaving some CASSINI instruments "ON" during the Probe checkouts may generate additional traffic on the data bus and somewhat jeopardize the proper Huygens sequence, and the relevant TM acquisition.

Huygens side :

In theory, the feared anomalies can be classified in :

- catastrophic, leading to total or partial mission failure, experiment degradation
- severe, leading to a significant reduction in the reliability
- minor, leading to functionally compromise part of the running checkout.

Practically, Huygens implements a set of hardware and software barriers making the occurrence of a catastrophic event in checkout impossible upon a 1553 bus failure. Also, all HUYGENS telecommands are protected by CRCs, which prevents any "dangerous" telecommand to be erroneously processed.

A severe level failure case has been identified : a specific checkout telecommand is sent to indicate to the experiments that they are running a checkout. If this command, because of a 1553 anomaly is not received by GCMS, it will activate its valves, which may significantly affect its reliability for the "real mission". It shall be pointed out that the relevant telecommand is sent twice in a sequence; to get a problem, both telecommands should be non operative.

Minor level anomalies may happen each time a telecommand will be missing. Even though the validity of the running checkout could be compromised, this won't affect the short or long term health of the Probe.

CASSINI side :

IOM 3412-CAS-CDS describes CASSINI data transmission/collection principles. A proposal is made to mute the instruments which will be kept "ON", with the consequence that any telemetry collection from these instruments will be suspended.

This mechanism is believed to efficiently reduce the impact of "CASSINI instruments in sleep mode" on the normal data bus traffic during Probe checkout, and is therefore fully approved.

Conclusion :

One can state that the muting of the powered instruments further reduces the impact of that configuration change on the expected bus traffic. On the other hand Huygens design and mode of operation strongly limits/eliminates the risk of any erroneous command to be executed.