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RESUME D'AUTEUR

Ce document présente l'évaluation technique de la sonde HUYGENS pendant le quatrième « cruise check out » qui a eu lieue le 15 Septembre 1999, un mois après la manoeuvre de Flyby de la terre

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1. SCOPE

The present report covers the fourth flight cruise check-out (F4) performed in the frame of the phase F of the HUYGENS Probe

F4 was run at launch + 23 months on the 14 & 15 th of September 1999.

The document aims at analysing the behaviour of the HUYGENS Probe System and subsystems during the test.

Note that experiments behaviour analysis is not part of this document.

In addition,

- The present analysis is based on the data downloaded in near real time to HPOC/ESOC during F4 through CASSINI high Gain Antenna and via a single DSN pass, and JPL. It was later cross checked with the same data recorded on board CASSINI SSR , and downloaded the day after F4.
- The reference test for comparison is mainly F2 run on the 27th March 1998 at launch+6 months, and F3 run on the 22nd of December 1998at launch+14 months.
- After some processing all the engineering data plots were delivered to ALCATEL on the 17th of September and all the status values were made available on the data server.

APPLICABLE DOCUMENTS

The tests have been performed according to the following documents:

- AD01: ESOC F4 sequence : DODS-SMD-HUY-FOP-001, issue 2.4
- 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 F4 Checkout Operational Report
  Doc. n° TOS-OF-HFR-004 Issue 1, date 10/99

3. CONFIGURATION

3.1. SPACECRAFT CONFIGURATION

– F4 has happened 1 month after CASSINI Earth Fly By. The Spacecraft is in cruise towards Jupiter with the -Z axis oriented to the Sun in order to have the High Gain Antenna shadowing the rest of the spacecraft. At the time of F4 the spacecraft-Sun and Spacecraft-Earth axis are basically aligned.

– The accuracy of the HGA pointing to the Sun is TBD mrad

– The relative distance to the Sun is ~1.3 AU (see Fig 3.1) and to Earth is~0.3 AU

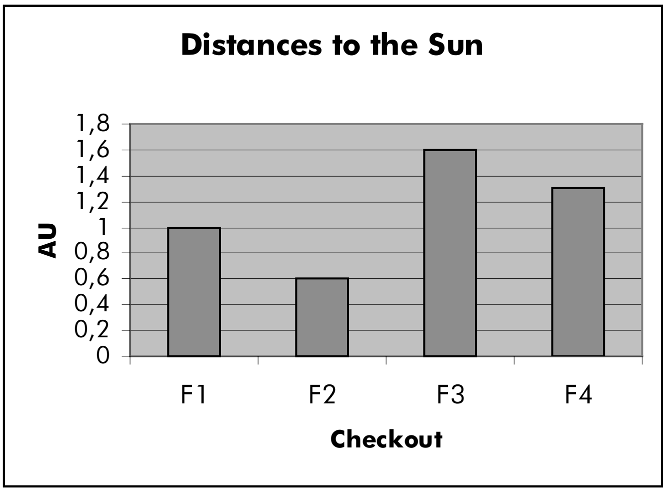


Fig. 3.1: CASSINI – Sun distance

– The CASSINI Telecommunication Subsystem status during F4 is TBD.

3.2. RADIO FREQUENCY SUBSYSTEM

TBD

4. FLIGHT CHECK OUT 4 (F4)

4.1. OPERATIONS

F4 consists in the execution of a so-called Checkout scenario 1b (CO#1b), ie a simulated descent, where the " b " indicates that the link on the chain A uses TUSO & RUSO. It also comprises :

⇒ 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,

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

The relevant SASF was loaded on board CASSINI, then executed at a pre-programmed time : execution start was 23h00 UTC on the 14/9/1999. As already mentioned, thanks to the relative alignment of the spacecraft-Sun-Earth vectors, CASSINI HGA was pointed towards the Earth, making feasible a real time transmission of the data. Probe telemetry was down linked at a 248.85 kbps rate via the DSN station in Madrid.

The F4 architecture is based on:

– PSA activation through Orbiter CDS "power on" TC at S_0-60 mn

– Dump SASW A/B EEPROM at S_0-40mn

– Probe wake up by the CASSINI Orbiter via the Solid State Power Switches at S_0-24 mn

– 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 TUSO and RUSO (DWE)

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

– ACP is in dormant mode during the first 110mn then in "mechanisms check mode" from 140 to 153mn. *Special commands are sent to open the P2 valve.*

- GCMS runs a simulated descent, with valves disabled by TCs:
- DISR runs a descent, with Spin simulation by TCs
- DUMP POSW A/B EEPROM starting at So+164mn53sec

The F4 "as run" key events are:

EVENTS	SEQUENCE TIMING	EXECUTION TIME IN UTC
PSE turn on	S0-01:00:00	1999-257 T23:00:00
RUSO ON	S0-00:59:44	1999-257 T23:00:16
Select RUSO	S0-00:58:43	1999-257 T23:01:17
PROBE turn on	S0-00:34:40	1999-257 T23:25:20
TUSO ON	S0-00:34:24	1999-257 T23:25:36
Select TUSO	S0-00:34:19	1999-257 T23:25:41
To detection		1999-258 T00:00:06.375
PROBE OFF	S0+2:45:58	1999-258 T02:45:58
PSA's OFF	S0+2 :46:52	1999-258 T02:46:52

One shall note that in total, F4 duration is 3h46mn, while F3 duration was 3h37mn, and F2 duration was only 3h04mn.

4.2. RESULTS

As already mentioned, the analysis is based both on engineering data plots received ALCATEL on the 20.09.99 and data, mainly the various status, retrieved from the ESOC server on the 17/9/99.

As already mentioned, reference for the analysis is F2, **a CO#1a performed on the 27th of March 1998**, but also F3, a CO#2 performed on the 22nd of December 98, which was using TUSO and RUSO on the A chain

The main outcomes of the evaluation are:

- the timing requested by the scenario are correctly followed by the CDS and all 348 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 F4, per function.

4.2.1.Frames and packets structure

This section deals with the review of the data basically 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, together with a monotonous increase of the Seq. Count is nominally reported on both chains when the Probe is not yet powered. Similarly the RT Count on both chains increases and resets when the Probe is OFF.

- **Probe HK packets Delta Seq. Counts**: a Delta value of 1 is nominally reported on both chains for HK1, 2 & 3. A Delta 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 $T_{probe\ ON}$.

4.2.2.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 TUSO and RUSO
- CASSINI HGA is pointed towards the Sun:

- **PSA secondary voltages**: PSA 12 V, 5 V and LNA supply voltage (nominally 12 V), are in their nominal range and perfectly stable over the test.
- **RUSO status**: RUSO is turned ON 16 s after PSA A is ON. RUSO reports lock status at about RUSO ON+16 mn s, well in line with expected behaviour and F2 results.
- **TUSO status**: TUSO is turned ON 16 s after Probe is ON. TUSO reports lock status at about TUSO ON+19.5mn, 3.5mn later than during F3. This is explained by DWE by the coldest initial TUSO temperature. Note that the mission timeline permits warm up duration of up to 30mn.
- **TCXOs status**: TM nominally reports TCXO selection on B Chain, and not on A Chain.
- **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. On Chain A, state 6 (carrier, subcarrier, bit sync and Sync Marker locked) has been reached after about the **6th** attempt to switch to Basic Frequency; this is identical to F3 case (it shall be noticed that F1 showed a complete receiver lock on chain A during CO#2 at the **3rd** attempt ; and on ground at worst, lock was achieved at the **2nd** attempt). As noted for F3, this is not a concern (in total the sequence plans 28 attempts to switch to basic frequency) and it is strongly believed this phenomenon to be related to the initial T° of TUSO : it is very similar for F4 and F3 and quite low (12.5°C against 10°C because of a greater Sun-spacecraft distance during F3) and while it was higher during F1 ; this leads to a longer time for the oscillator frequency to stabilise and enter in the 30kHz PSA acquisition bandwidth. It should be pointed out again that this problem will not happen during the mission : about 30mn TUSO warm up time is foreseen before PSA attempts to acquire the Probe RF signal, in doppler mode (at that time, the frequency variation of the transmitted signal will be far below the requested 30kHz)

  As expected, on Chain B (no TUSO/RUSO), switch to basic frequency happens at the 1st attempt.
- **AGC**: The table hereunder evidences the evolution since the launch campaign at

KSC. The AGC level for F4 is well in accordance with conclusions reached after the AGC specific test (see RD3)and confirmed by F3.

TEST	AGC A	AGC B
CO#2 mated in PHSF	-96 dB +/-0.4 /decrease 0.7 dB	-95.5 dB +/- 0.2 /decrease 0.4 dB
CGCK on the pad	-100.5 dB +/-1 dB modulated 2.8 dB	-96.5 dB +/-0. 3 modulated 1.3 dB
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** (*)	**-97 dB +/-1dB**

(*) the AGC TM exhibits about 20mn period oscillations which have been demonstrated to be due to CASSINI ACS pointing accuracy.

- NCO: as far as the Probe System is concerned, NCO frequency changes are as expected, both on chain A (RUSO) and chain B (TCXO) ,and very similar to F1. Nevertheless, DWE have noticed a NCO frequency modulation similar to those observed during F1& F3 (0.367Hz) with a maximum amplitude oscillation of 17Hz (see DWE report) It shall be noticed that this is currently **not a Probe System concern.** Finally, so called dF/dt parameters on both chains are within the expected range.

4.2.3.Power

- CASSINI Telemetry has shown :
  - PSA A power consumption ranges from 40W during RUSO warm up phase, down to 32W afterwards,
  - PSA B average consumption is 25W , which means a total PSE steady state consumption of 57W
  - Probe total average maximum consumption is 149 W

Both values are well in line with reference test results.

- **All Current limiters status and Pyro relays status** have been cross checked on the retrieved data. Especially, the Selection Relay Status parameters have been analysed. No anomaly was noticed : current limiters status are in line with the expected units power status and corresponding current telemetry, while the pyro relays set and reset is reported as planned.
- **Main bus voltage** is 28.09 Volts, as expected.
- **Batteries voltages** telemetries at the end of the test are comprised in between the telemetries reported during F2 and F3

	F2	**F4**	**F3**
battery 1 A	2.00 Volt	2.6 V	2.93 V
battery 2 A	2.00 Volt	2.28V	2.6V
battery 3 A	1.00 Volt	1.3 V	1.3 V
battery 3 B	1.00 Volt	1.3 V	1.3 V
battery 4 B	2.00 Volt	2.3 V	2.6 V
battery 5 B	1.63 Volt	1.96 V.	2.28 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 leak current in the measurement diode. However, the fact that the measured value are comprised between F2 & F3 cases is simply correlated to the respective PCDU temperature conditions during F2, F3, & F4 (see § 4.2.6.). This is a normal behaviour.

The lower battery 3 voltage parameter reflects the cross trapping of the relevant telemetry.

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

	Pre To	**To To+110 mn**	**To+140 mn**	**To+154 mn**	**Reference test**
BDR1	0.55 A	0.82 A	0.78 A	0.5A	F2+F3
BDR2	0.49 A	0.72 A	0.70 A	0.45A	F2+F3
BDR3	0.49 A	0.72 A	0.70 A	0.45A	F2+F3
BDR4	0.49 A	0.72 A	0.67 A	0.45/0.55 A	F2+F3
BDR5	0.55 AA	0.82 A	0.78 A	0.5 A	F2+F3

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

UNITS	CURRENT	UNITS	CURRENT	Reference test
TX A	0.19 A	**TX B**	0.195 A	F3 A
TUSO N	0.32 A warm up 0.13 A steady state	**TUSO R**	0.3 A warm up 0.123 A steady state	F3
CDMU A	0.326 A	**CDMU B**	0.337 A	F3
Prox Sensor A	0	**Prox Sensor B**	0	-
DISR1 N	0.16 A/peak 0.23 A	**DISR1 R**	0.15 A/peak 0.22 A	
DISR2 N	0	**DISR2 R**	0	F2
GCMS1 N	0.28 A in pre To 0.4 A in post To	**GCMS1 R**	0.26 A in pre To 0.38 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	F3
HASI2 N	0	**HASI2 R**	0	F3
ACP1 N	0.07 A	**ACP1 R**	0.07 A	F2
ACP2 N	0	**ACP2 R**	0	F2
ACP3 N	Peaks up to 0.80 A	**ACP3 R**	Peaks up to 0.95 A	F2
SSP N	0.32 A	**SSP R**	0.027 A	F3

4.2.4.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 and 2B).

  For the accelerometer 1, 1A, 1B, an average nominal value of 0g is noticed on both 1A and 1B TM, but with spurious 1 LSB peaks.

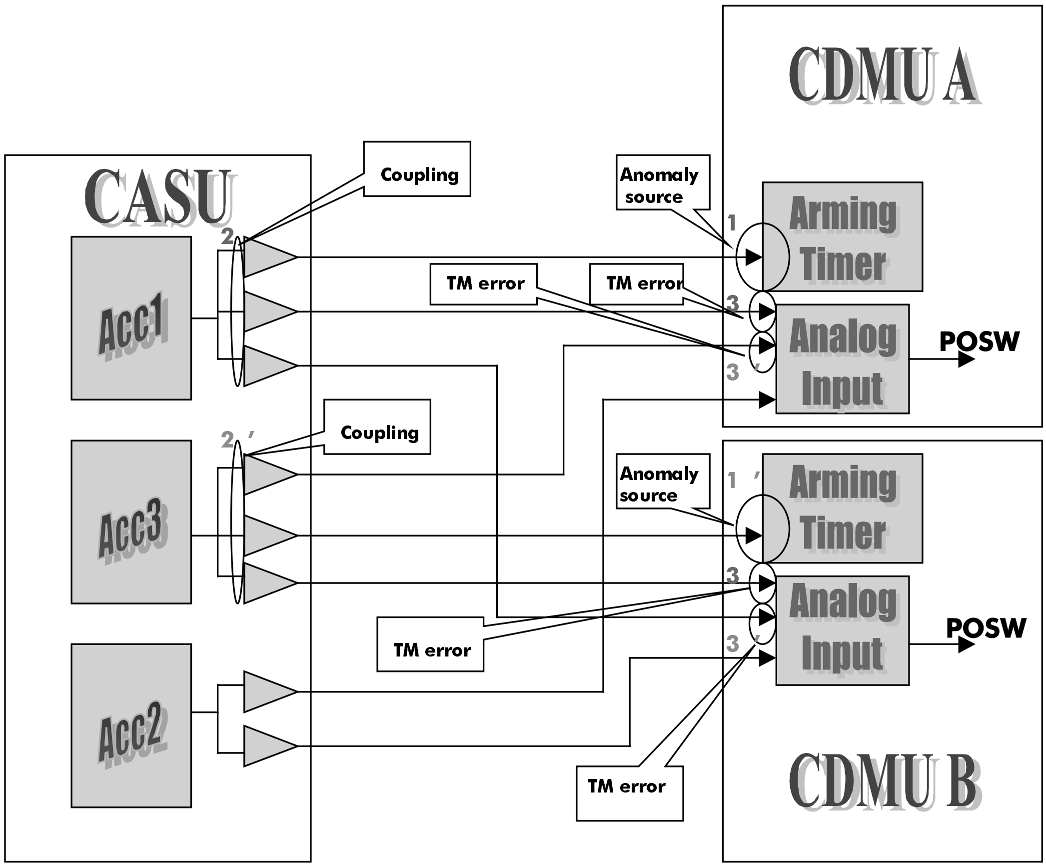
Accelerometer 3 TM on chain A and B exhibits an average value of 1 LSB during the 2 first third of the test; during last third, 3A and 3B TM average value returns to 0g with many 1 LSB noise peaks... It shall be noted, again, that 1 LSB represents 20mV or 0.04g, which, compared to the about 1g detection threshold which will trigger the Arming Timer and Descent timeline, corresponds to an error of about 4%.

This anomaly on the accelerometers 1 and 3 telemetries was already evidenced during F1, F2 and F3. 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.

The situation actually slightly improved w.r.t. F3.

F3 report explained the noticed noise as possibly coming from a stiction effect at the level of the accelerometers 1 & 3, similarly to what was observed by the CASU contractor, LABEN, during the FM unit testing, leading to more than 10mV offset at the CASU output.

Another possible source of the anomaly could be, as illustrated in the schematics hereunder, at the level of CDMUs Armina timer inputs, which could propagate to other CASU outputs, then be reported as errors in the telemetry. This mechanism may explain the noticed TM spurious on both "1" and "3" outputs as seen by CDMU A and CDMU B. It however implies a design susceptibility at the level of the Arming timer interface in the CDMUs, and shall be consolidated through a dedicated circuit analysis.



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

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

– **DDB F1 & F2 flags status**: S_0 "detection" is correctly reported on both chains through F1 change. F2 nominally reports the TAT use over the whole sequence.

– **DDB Time**: For both chains, in line with Probe Real Time before T_0, then with Probe Mission time from T_0 (from Tp + 36 mn to T0+165 mn 52 s).

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

– **DDB Spin** : TM reports Spin value in accordance with #CO1 alteration TC's, ie :

- 7rpm < Spin < 9rpm during the first 15mn of the descent
- a peak of 12.5rpm at T0+25mn
- a constant decrease during the rest of the descent down to 2rpm

– **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 and F3.

– **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 F3. No difference between F3 and F4 was noticed for all 4 memory banks, showing a good immunity of the CDMUs an 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 F4 duration.

4.2.5.On board software

4.2.5.1. 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 F4, 10#7068 is identical to F1, F2, & F3 tests data.
- **SASW CUT Processing Time**: It reflects the processor load for each CUT. As expected, and as per F1, F2 & F3, processing time ranges from 16 ms to 27 ms, 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 <120 ms. 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 F4, on both chains, **DTStart** nominally happens 18.7 ms after the CUT start; processing duration is in average 1.4 ms, 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 RTI (therefore CASSINI clock) drift w.r.t. the Probe (CDMUs) clocks.

  This drift is measured to be for both chains of about 45 ms over the test duration (about 3 h), in line with reference test results: this demonstrates that the CDMU oscillator stability has not changed. Processing duration, given by **FDI EXEC** parameter is in average 0.8 ms, in line with the reference tests results.

- **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, 1.4 ms, in line with the reference tests results.

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

4.2.5.2. 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 F4, 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 55 % max. A slow increase of the processor load from T0 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 F4 is very much comparable to F2, and denotes a correct operation of the software over the whole checkout.

4.2.6.Thermal

4.2.6.1 Cruise check out F4

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 summarised in the table hereafter:

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

Temperatures values acquired by the HUYGENS Probe are summarised in the table hereafter:

a. Descent module External units:

TM IDENTIFICATION	T° SENSOR	F4 MEASUREMENTS (15/09/99)			F3 MEASUREMENTS (22/12/98)			F2 MEASUREMENTS (23/10/97°		
	Location	T init	T end	**Delta**	T init	T end	**Delta**	T init	T maxi	**Delta**
1A	SEPS A	-47.7	-47.7	**0**	-50	-50	**0**	-44.1	-44	**0.1**
2B	SEPS A	-47.7	-47.7	**0**	-49.5	-49.5	**0**	-44.1	-43.6	**0.5**
1B	SEPS B	-49.5	-49.5	**0**	-53.5	-53.5	**0**	-47.7	-47.7	**0**
2A	SEPS C	-51.7	-51.7	**0**	-54.3	-54.3	**0**	-48.2	-48.2	**0**
3A	PJM A	-26	-25.3	**0.7**	-28	-27.2	**0.8**	-23.5	- 22.2	**0.7**
3B	PJM B	-24	-23.4	**0.6**	-25.7	-25.3	**0.4**	-21.5	-20.9	**0.6**
4A	PJM C	-25	-24.7	**0.3**	-26.9	-26.5	**0.4**	-22.9	-22.5	**0.4**
4B	PDD	-21.5	-21.3	**0.2**	-23.2	-23.1	**0.1**	-18.7	-18.7	**0**

b. Descent Module Internal units

TM IDENTIFICATION	Sensor Location	F4 MEASUREMENTS (15/09/99)			F3 MEASUREMENTS (22/12/98)			F2 MEASUREMENTS (23/10/97)		
8A	PCDU	12	33.7	**21.7**	10.8	31.2	**20.4**	15	33.5	**18.7**
5A	BATT 1A	16.5	21.8	**5.3**	15	19.4	**4.4**	18.1	22.7	**4.6**
8B	BATT 1B	16.5	21.8	**5.3**	13.1	19.4	**6.3**	15	23.6	**8.6**
6B	BATT 2A	13.1	24.5	**11.4**	11.2	22.7	**11.5**	18	25.4	**7.4**
7B	BATT 3A	14.3	21.8	**7.5**	15	19.4	**4.4**	16.3	22.7	**6.4**
6A	BATT 3B	12.5	21.8	**9.3**	10.8	19.4	**8.6**	14.4	21.8	**7.4**
5B	BATT 4B	15.7	21.7	**6**	14.4	20	**5.6**	17.5	23.6	**6.1**
7A	BATT 5A	16.5	22.7	**6.2**	15	20.9	**5.9**	18.1	24.5	**6.4**
9A	TX A	14	32.5	**18.5**	13	30	**17**	17	32.5	**16.5**
9B	TX B	14	29.1	**15.1**	13	24.3	**11.3**	16.2	30	**13.8**
10A	GCMS	14.5	29.1	**14.4**	13	27	**14**	22.8	35.9	**13.1**
10B	TUSO	12.5	36.2	**23.7**	11	35	**24**	15	27.3	**12.3**
11A	DISR I/F	-25.5	-24.7	**0.8**	23.4	-26.6	**0.6**	-23	-22.5	**0.5**
11B	DISR SH	2.5	8.6	**6.1**	1	5.9	**4.9**	5	9.1	**4.1**
12A	FOAM int	9.5	25.4	**15.9**		23.6	**15.6**	11.5	25.5	**14**
12B	CONE (foam ext)	-17.5	-15.2	**2.3**	-19.5	-17.1	**2.4**	-15	-13.5	**1.5**

c. Internal units T° reported through the Probe TM are summarised in the table hereafter:

IDENTIFICATION	F4 MEASURED RANGE INIT T° → END T°	F3 MEASURED RANGE INIT T° → END T°	F2 MEASURED RANGE INIT T° → END T°
RUSO Lamp	112.5° C → 112.5° C	113° C → 113° C	101.7° C → 101.7° C **(1)**
RUSO resonator	75° C → 75° C	75° C → 75° C	64.4 °C → 64.4 °C **(1)**
RUSO crystal	72° C → 73° C	72° C → 73° C	64.4 °C → 64.4 °C **(1)**
TUSO Lamp	112.5° C → 112.5° C	112.5° C → 112.5° C	101.7 °C → 101.7 °C **(1)**
TUSO resonator	76.5° C → 76.5° C	76.5° C → 76.5° C	64.4 °C → 64.4 °C **(1)**
TUSO crystal	74° C → 75° C	74° C → 75° C	64.4° C → 64.4° C **(1)**
PSA A Temp	22° C → 40° C	18° C → 37.3° C	21.7 °C → 39.1 °C
PSA B Temp	22° C → 40° C	18° C → 36.4° C	21.7 °C → 39.1 °C
Tx A HPA	14° C → 33.3° C	13° C → 31.6° C	16.5 °C → 34.9 °C
Tx B HPA	14° C → 31.2° C	13° C → 28.8° C	15 °C → 31.6 °C
CDMU A DC/DC 1	13° C → 37.5° C	12° C → 35° C	16 °C → 35 °C
CDMU A DC/DC 2	13° C → 33.7° C	12° C → 31.3° C	15 °C → 32.5 °C
CDMU B DC/DC 1	12° C → 33.7° C	11° C → 31.3° C	15 °C → 32.5 °C
CDMU B DC/DC 2	12° C → 30° C	11° C → 29° C	15 °C → 30 °C

(1) These figures correspond to the TM reported when the unit is OFF.

<u>Conclusion:</u>

The initial steady state temperature, only related to the spacecraft-Sun distance because of identical orientation conditions (CASSINI HGA is pointed to the Sun for F2, F3 and F4), is slightly cooler than during F2, and hotter than during F3; this is reflected in most of the measured temperatures, with the delta ranges presented below :

	F4-F2	F4-F3
Average delta initial T°	-2 to -3°C	+1 to +2°C

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

It is in addition fully in line with F3 and F2 measurements, with generally higher units temperatures increases due to the longer duration for F4 compared to F2 & F3. Especially, F4 compares very well to F2, with the exception of TUSO and RUSO T° (OFF during F2).

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

4.2.7.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 behaviour analysis shall be found in the PI's F4 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 related to CASSNI, and especially CASSINI experiments operations which have or may have an impact on the Huygens Probe System in the F3 to F4 review time frame.

Basically, during this period, a concern about the Radio Front End (RFE) unit thermal behaviour during operation of the CASSINI Radio Science experiment was re-opened.

The problem, pointed out during the post F3 Instruments Checkout (ICO) phase, consists in a RFE temperature increase by about 20°C over typically 3 hours, in OFF condition, each time the RSS experiment is in activity.

This point was already addressed in the frame of the F3 report (RD4), where the rationale for the anomaly is described (losses in a circulator located inside the RFE). Also, the important question of the RFE compatibility with a possibly high number of thermal cycles of limited amplitude was discussed.

At F3 report time, the estimate of the number of such cycles, as provided to ALCATEL, was 30, and the RFE manufacturer, SAAB Eriksson Space (SES) stated the RFE design and manufacturing would comply with these limited thermal cycles (see RD04).

A few time after F4, the estimate of the total number of RSS S-band operations raised up to 60, and SES refused to state on the RFE compatibility with such a number of cycles (see Annex 1.1).

Consequently, ALCATEL, considering in full agreement with SES, that the tests performed in the frame of the unit qualification process were not representative enough of its anticipated use, refused in a first approach to formally commit on the RFE compliance with the specified cycling (see Annex 1.2).

However it is understood that the positive resolution of this issue is of the highest importance for the RSS and the related science return. This therefore implies further efforts in order to establish convincing arguments in favour or possibly against the RFE capability to sustain the mentioned cycling. This will eventually consist in :

1. the detailed analysis of the RFE heating process during RSS operation in order to determine the potentially stressed parts and processes, and the extend of the stress,

2. the analysis of the parts and processes used in the RFE manufacturing in order to assess their compliance with the cycling effects as derived from 1.,

3. should the steps 1 & 2 be not convincing enough, the performance of a dedicated thermal test on the available QM RFE, this test being defined to exactly match the flight configuration.

The above sequence is believed to permit the most reliable analysis of the discussed post Launch anomaly, related to unexpected, and therefore non specified mode of operation.

6. CONCLUSION

The fourth Cruise Check out was completed on the 15th September 1999, one month after CASSINI successful Earth Flyby, and at a distance from the Sun of ~1.6AU.

All the Huygens sub systems operated nominally, and the RF link through the HGA was excellent without loss of any packet and data and with an AGC in accordance with the expected value due to the Sun interference.

However one still unexplained anomaly, already evidenced in the previous checkouts, and discussed in F3 report, was again flagged and still needs to be carefully monitored :

- accelerometers 1 and 3 noise level

Additionally, the RSS test leading to RFE temperature increase, as noticed during the ICO which has followed F3, is planned to be reproduced up to 60 times, instead of 30 as expressed initially.

<u>ALCATEL do not currently commit</u> on the RFE compatibility with the anticipated cycling, and consider further detailed analysis to be mandatory.

Annex 1.1 : SES Statement related to RFE use

Saab Ericsson Space

TELEFAX

Document No: HUY/TEL/0362 /SE

Date: 29 Nov 1999 Page: 1/1

To: Alcatel, Cannes
Attn: Mr. P. Couzin

Telefax No: 0033-4 9292 3330

From: Jan Persson

Telephone No: +46 31 735 4427

Project: Huygens

Subject: RFE

Reference: Huygens 21/99

Internal distr: DLJ, RS

Looking at your new requirements, it is very hard to define the exact limit, where you would find a degradation, permanent or temporary, due to such use.

After a review of the materials and processes involved in the RFE we can only state that extensive thermal cycling will degrade the equipment.

The temperature span and the number of cycles suggested by you is not very large, but since our data base on such use is limited, any exact number can not be given.

Best regards,
Huygens programme

Jan Persson
Project manager

Annex 1.2 : ALCATEL recommendation related to RFE use

Alcatel Space Industries **Etablissement de Cannes** 100, bld du Midi BP 99 06156 Cannes la Bocca Cedex France	ALCATEL	Date : 6/12/99 Nb Pages : 1/3 Ref : 28 / 99

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Objet / *Subject* : RFE THERMAL STRESS	

Hi Gentlemen,

You will find in appendix 1 SAAB statement on the ability of the RFE to cope with a number of « thermal cyclings » related to RSS operation, increased to 60.

Initial questions to SAAB are in appendix 2.

Considering that SAAB first stated the RFE would comply with 30 « thermal cyclings », and then expressed concerns when this figure went up to 60, ALCATEL position is :

- we support SAAB concerns with an increased number of cyclings, considering that the argument of lack of data base on the behaviour of RFE like equipment when submitted to numerous thermal stresses (even limited in range) is a particularly valid one,

- we recommend ESA not to accept a number of RSS operations which would lead to RFE thermal stress, greater than **30**. An additional number of operations, say by steps of 5, could be agreed provided that the RFE performance after these first 30 cycles, as monitored during the Probe checkouts, remains unchanged.

Best regards