PLASMIC PROPULSION LIFETEST

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ABSTRACT

This article is related to the overall functional chain life test, representative of the SPACEBUS plasma propulsion system. The plasma propulsion subsystem developed by ALCATEL SPACE INDUSTRIES will undergo a life test in order to demonstrate the PPS subsystem operation on ground over a flight representative mission and in flight representative conditions.

ALCATEL SPACE INDUSTRIES as the Prime Contractor for this life test, specifies and manages this test.

The life test is part of the ground qualification process of the SPACEBUS plasmic propulsion subsystem. It will include 3700 on/off cycling on SPT 100 and 7400 on/off cycling on PPU with vacuum and temperature controlled conditions. It will accumulate 6500 hours and 1.87 million Ns of total impulse. It will be realised by SNECMA in their Villaroche's facility in France and will take place between Mid'99 and Mid'2001.

The functional chain will include the following flight standard H/W:

- one Stationary Plasma Thruster (SPT 100) developed by FAKEL in Russia
- two Xenon Flow Controllers (XFC) developed by FAKEL in Russia ;
- one Power Processing Unit & Thruster Selection Unit (PPU/TSU) developed by ALCATEL ETCA in Belgium ;
- one Filter Unit (FU);
- one series redundant mechanical pressure regulator
- a set of representative tubing and harness developed by ALCATEL SPACE INDUSTRIES and SNECMA.

The ground support equipment will include :

- one simulator of the SPT 100 (to simulate the second thruster) ;
- one Electrical Ground Support Equipment (EGSE) in order to command and control the PPU ;
- one Xenon storage tank ;
- one instrumentation set.

Prior to the life test, SPT 100, XFC and PPU are submitted to full performance and environmental qualification and acceptance tests.

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INTRODUCTION

This article presents the facility, the tested hardware, the test set-up and the ground support equipment, the test sequences, the expected results, the current progress & results.

The objective of this test is to demonstrate capability of the PPS subsystem to operate in an environment simulating the orbit conditions.

I EQUIPMENT

The test shown in the figure 1 includes the following flight representative equipment of the subsystem :

- One SPT 100
- Two XFC
- One PPU EQM
- One FU QM
- One pressure regulator

The SPT, XFC, FU and PPU have been submitted to qualifications tests before being included in the life test. The pressure regulator was testing in acceptance tests.

The electrical harness were made as flight type as possible with critical attention paid to representative grounding schemes, shielding and filter configurations.

In order to operate the TSU, the thruster simulator is used and act as a load equivalent to the thruster electrical behaviour. The switch is operate alternatively to the thruster firing.

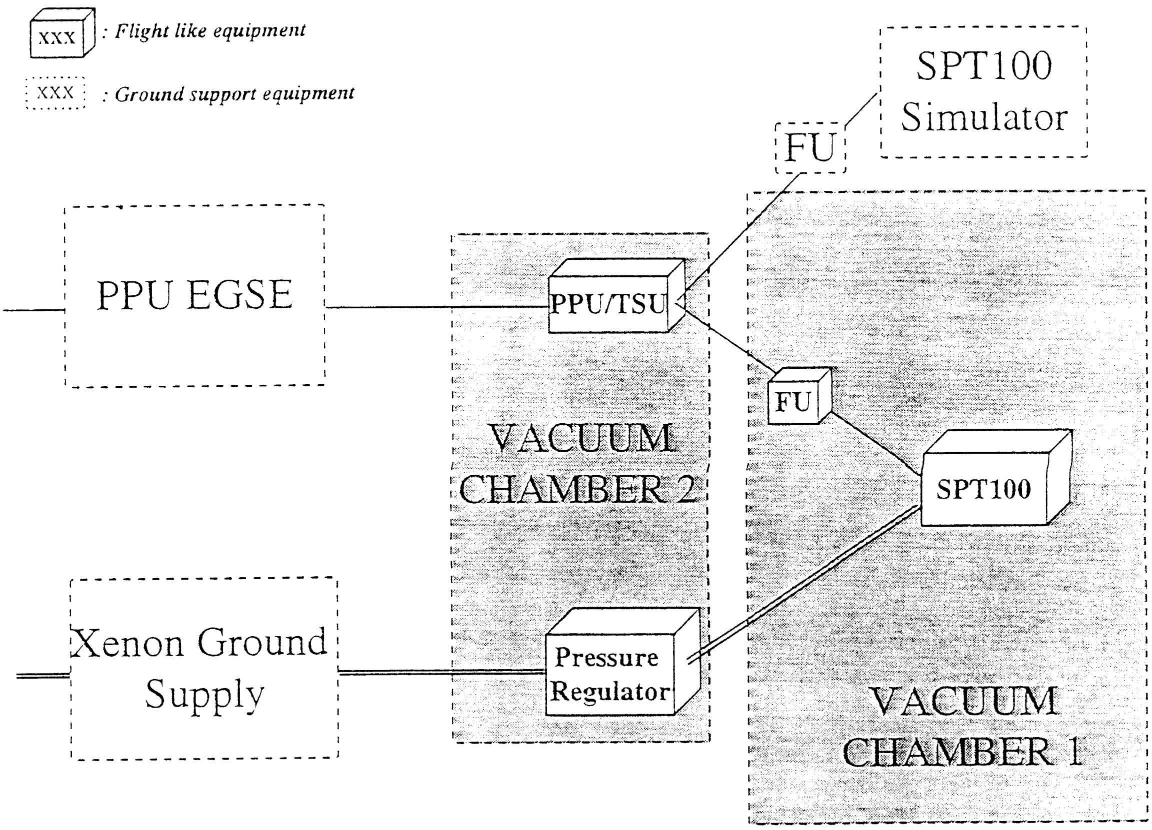
As EGSE is used to simulate the satellite command. The main functions are :

- to provide electrical alimentation satellite bus and equivalent impedance (LISN)
- TM/TC interface and acquisition

Xenon alimentation is provide using a bottle of Xenon (60 to 5 bar) simulating the tank.

A Xenon supply assembly equipped with the flow meters and Xenon pressure sensors.

The Logiciel de Pilotage d'Essai (LPE) is the main computer, test sequencer and test monitoring and measurements storage.



XXX : Flight like equipment
XXX : Ground support equipment
SPT100 Simulator
FU
PPU EGSE
PPU/TSU
FU
VACUUM CHAMBER 2
SPT100
Xenon Ground Supply
Pressure Regulator
VACUUM CHAMBER 1

II TEST SET-UP

A. FACILITY

The SNECMA life test facility shown in figure 2 consists of

- a big vacuum chamber containing the thruster, the XFC and the FU,
- a small vacuum chamber containing a PPU and the pressure regulator,
- an Electrical Ground Support E (EGSE) with a LISN,
- a Logiciel de Pilotage d'Essai (LPE), a static simulator,
- some measurements cupboards,
- an Opto cupboard,
- a high pressure facility,
- a low pressure facility,
- and a hardware security cupboard.

The main vacuum chamber is equipped with thermal sensors and vacuum transducers, it allow the thrust measurement device and the plume characterization.

The small vacuum chamber is also equipped with thermal sensors, vacuum transducers and permit the thermal regulation.

The measurements cupboards allow all electrical measurements necessary for the test security and monitoring between the PPU, the thruster and the simulator.

The Opto board permit the measurement interface between LPE and the sensors.

The Hardware security cupboard is independant from LPE or EGSE behaviour, is cabled logic system commanding high pressure valve and electrical power.

B. TEST MEANS

The vacuum system comprises one vacuum chamber and its pumping system, one air lock and its pumping system, one valve separating the chamber from the air lock and a baffle cooled with liquid nitrogen.

The maximum vacuum in the chamber is less than 10^{-6} mbar. With a Xenon supply of 5.5 mg/s, the pressure is established at less than 5.10^{-5} mbar. The pumping capacity between two regeneration is better than 10 kg for the test. The back of the chamber including the baffle are protected by a carbon wall and the vacuum chamber of LIB by a stainless steel ring.

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The Xenon supply system comprises one nitrogen infeed line to clean-up the overall lines, one Xenon in feed line, one supply line for the XFC module and one vacuum circuit.

The supply line is equipped with a mass flow meter/controller which regulates the quantity of

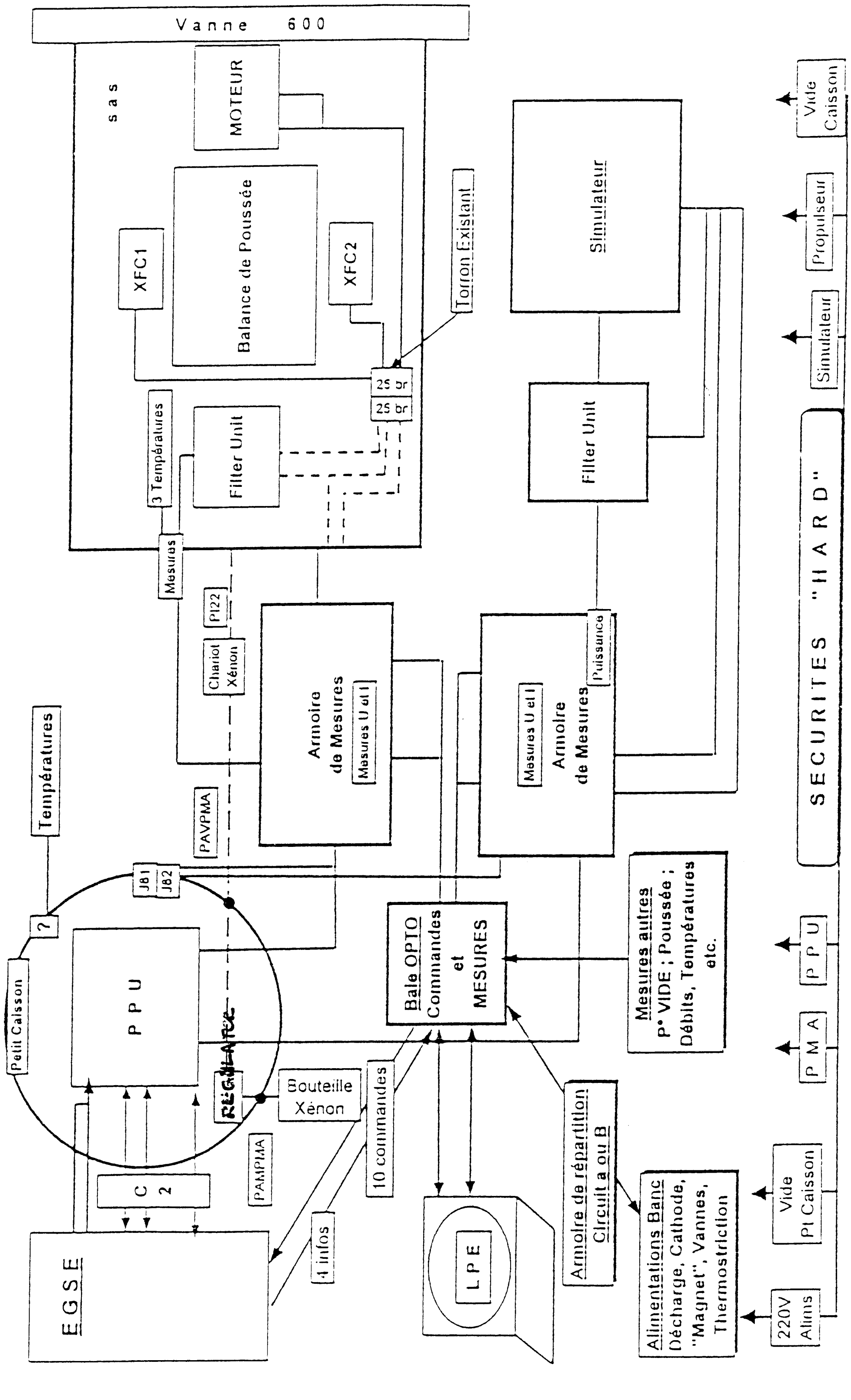
Xenon flowing through the line to a maximum of 8 mg/s. When the XFC module is installed, the controller function of the Xe flow meter is disconnected.

The PPU is placed in the small chamber on a radiation plate for thermal control regulated at 50°C.

C. TEST INTERFACES

A schematic of the integrated test schematic is shown in figure 2.

The integrated test configuration was made as similar as possible to the flight subsystem.


Vanne 600
sas
MOTEUR
Balance de Poussée
XFC1
XFC2
Torron Existant
25 br
25 br
3 Températures
Filter Unit
Mesures
P122
Chariot Xénon
Armoire de Mesures
Mesures U et I
PAVPMA
Simulateur
Filter Unit
Puissance
Mesures U et I
Armoire de Mesures
SECURITES "HARD"
Vide Caisson
Propulseur
Simulateur
P P U
P M A
Vide Pt Caisson
220V Alims
Températures
?
Petit Caisson
J81
J82
P P U
REGULATEUR
Bouteille Xénon
C 2
PAMPMA
EGSE
4 infos
10 commandes
Baie OPTO Commandes et MESURES
Mesures autres
P° VIDE ; Poussée ; Débits, Températures etc.
LPE
Armoire de répartition Circuit a ou B
Alimentations Banc
Décharge, Cathode, "Magnet", Vannes, Thermostriction

D. Data Acquisition

The automatic measurement acquisition, control and monitoring system, shown in figure 3, comprises one HP 362 microcomputer, two HP 3852A acquisition units plus an Opto22 panel, one printer one LINSEIS recorder and ensures the

functions of command of the thruster supplies, the Xenon supply assembly, the thrust balance ; the control and surveillance, that means check of acquired data compares them with progammable alarms and display them on computer screen, while commanding appropriate routing if necessary ; the acquisition and retrieval of measurements from the thruster, the XFCs, the thrust balance, the vacuum system and the Xenon supply system.

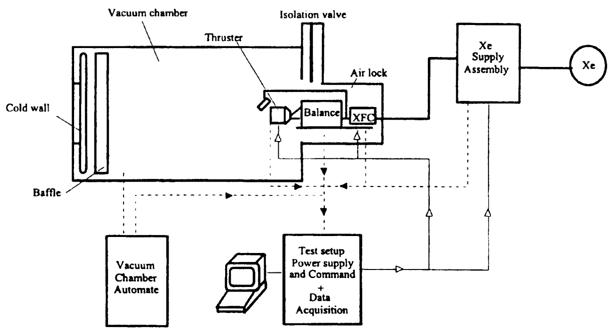


Figure 3

The balance shown in figure 4 is an important part of the test bench since the thrust measurement is the only parameter giving a mean of precisely determining the specific impulse and the efficiency of stationary plasma thrusters.

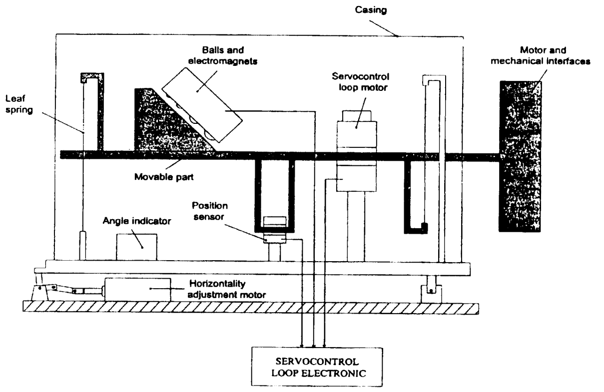


Figure 4

E. Measurements

The measurements during the life test are the electrical parameters between the PPU and the thruster (voltage, current on main discharge, cathode heater, thermothrottle, valves, magnet) ; the mass flow (thruster) and pressures (upstream, downstream from pressure regulator) ; the vacuum pressure in both chamber ; the temperatures (thruster, FU, PPU interface, simulator, pressure regulator) ; the storage frequency is less than 1 seconds ; the plume analysis and the thrust vector evolution (frequency : 500 hours of firing) ; the ceramic wall erosion (weekly, photographic method).

III Operation

A. Operational modes

3720 cycles will be performed on the thruster during this test at SNECMA France. Each test cycle includes one firing on SPT 100 (ON time : 1H51', OFF time : 45') and one firing on simulator (ON time : 15', OFF time : 15') and is shown on the figure 3.

7400 cycles will performed on the PPU during the test.

500 cold starts will be performed on the thruster SPT 100 (3 cycles per day) at FAKEL Russia. The thruster temperature start-up is -44°C for the first cycle, -25°C for the second and third cycle.

The cathode operation philosophy is 92 cycles on cathode A, one cycle on cathode B in order to protect the cold redundancy from chamber wall sputtering.

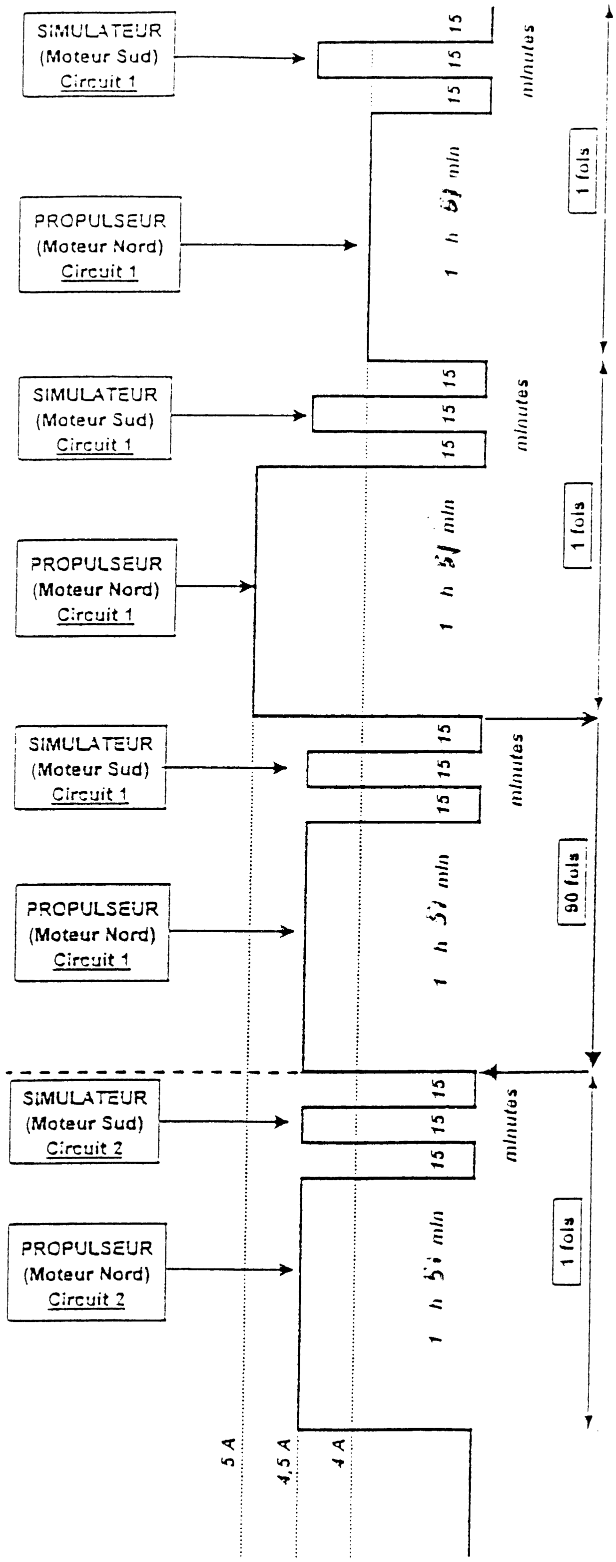
The operating point is 91 cycles at nominal point (discharge current is 4.5 A), one cycle at high operating point (discharge current is 5 A) and one cycle at low operating point (discharge current is 4 A).

B. Test sequence

The test sequence is shown in table 1 and figure 5 and shall be repeat 40 times :

Repeat	Cathode	thruster Assembly	ON	OFF	Operating point
1	B	SPT 100 Simulator	1H51 15'	15' 15'	Nom Nom
90	A	SPT 100 Simulator	1H51 15'	15' 15'	Nom Nom
1	A	SPT 100 Simulator	1H51 15'	15' 15'	Max Nom
1	A	SPT 100 Simulator	1H51 15'	15' 15'	Min Nom

Table 1



The temperature range during the test is shown in the table 2.

EQUIPMENT	TEMPERATURE
PPU	50°C ± 5 (thermal regulation)
SPT 100	3220 ambiant cycles + 500 cold cycles (-44°C, -25°C)
FU	ambiant
Xe Pressure Regulator	ambiant

Table 2

The Xenon bottle provided by Air Liquid with a Xenon purity who must be maintained with at least 99.996% purity.

IV RESULTS

The life test started on the 1999, 6th August.

Currently, around 350 hours duration firing, 190 cycles (+ 86 hours and 90 cycles in qualification tests) were performed on the thruster SPT 100 and have been 380 cycles on the PPU.

Some minor stop have been observed since the beginning of the life test and were attributed to the non flight hardware.

More exhaustion results will be shown and given at the IEPC conference.

V CONCLUSION

The 350 hours for the thruster and 380 cycles for PPU integrated tests has successfully verified operation of the PPS subsystem.

For the moment, all aspects of subsystem performance are within specification.

VI REFERENCES