SMALL GEO XENON PROPELLANT SUPPLY ASSEMBLY PRESSURE REGULATOR PANEL: TEST RESULTS AND COMPARISON WITH ECOSIMPRO PREDICTIONS

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ABSTRACT

The Small GEO Propellant Supply Assembly (PSA) is an electronic pressure regulator developed by IberEspacio for the Xenon management in the Electric Propulsion Platform System (EPPS) of the Small GEO platform. The PSA decreases the pressure from tank conditions (Maximum Expected Operating Pressure 186 bar) to an in-flight programmable set point (nominally around 2.2 bar), despite the downstream user, using a bang-bang logic. Two different propulsion units are fed: the Electric Propulsion (EP) unit, with a maximum Xenon mass flow of 10 mg/s, and the Cold Gas Thruster (CGT) unit, with a maximum Xenon mass flow of 200 mg/s. This paper reviews the results of the Xenon Functional Testing performed on the PSA Engineering Model (EM) in thermal vacuum chamber under completely flight representative conditions. The measured performances are presented, analyzed and compared to the EcosimPro modeling prediction made using ESPSS (European Space Propulsion System Simulation tool) library. The test campaign successfully covered the critical End of Life conditions for both downstream units at the minimum and maximum operating temperature (+20ºC/+50ºC). Key performance parameters like the actuation frequency of the system, and the pressure raise obtained downstream are reported as function of the upstream pressure.

SATELLITE AND PROPULSION SYSTEM OVERVIEW

The Small Geostationary Platform (SGEO) is being developed in the frame of ARTES-11 by a consortium headed by the OHB-System AG with a core team line-up including LuxSpace SARL, OHB Sweden AB (formerly known as the Swedish Space Corporation) and RUAG Space AG.

SGEO is a European cost-effective platform to address the segment of small telecommunications satellites in geostationary orbit up to 400 kg of payload mass, 3.5 kW (EOL) of payload power and a lifetime of up to 15 years.

The first SGEO satellite is currently under development for the HISPASAT AG1 (HAG1) mission and drives the satellite baseline design.

The SGEO spacecraft uses the Electrical propulsion subsystem (EPPS) to perform all orbital maneuvers with the exception of the transfer from Geostationary Transfer Orbit (GTO) to Geostationary Orbit (GEO), which is performed by a separate chemical propulsion system. The chemical propulsion system is optional in case of direct GEO injection [1] [2].

The SGEO EPPS is based on two Electric Propulsion (EP) thruster branches, denoted EPTA 1 (Electric Propulsion Thruster Assembly) and EPTA2, which operate in cold redundancy. EPTA 1 is composed of four HEMP thrusters while the redundant branch EPTA 2 is composed of four SPT-100.

In addition, there are two cold redundant Xenon cold gas thruster branches (CGTA).

Typical Xenon flow rates requirements for the EPTA assemblies are of 0.1-10mg/s, and 200 mg/s for the CGTA.

The Xenon Tank Assembly (XTA) is composed by two tanks, for a total volume of around 120 l. The nominal beginning of life pressure is 186 bar @50°C/93 bar @20ºC, connected in a blow-down mode configuration.

The Propellant Supply Assembly (PSA) connects the XTA to EPTA 1, EPTA 2 and CGTA, and is in charge of providing a constant downstream pressure despite the user.

SGEO PSA OVERVIEW

The SGEO PSA is composed by two parts [3]: a Pressure Regulator Panel (PRP), where the fluid control hardware is mounted on a dedicated base-plate, and Support and Control Electronics (SCE), with the purpose of powering, driving and monitoring the PRP. These units are two physically independent units.

IberEspacio, PSA Prime Contractor, is in charge of the PRP design of the hardware, assembly integration and testing and definition of the control logic. EADS Astrium Crisa, as IberEspacio's subcontractor, is in charge of the SCE design, manufacturing and testing.

The main functions of the PSA are:

- To decrease the Xenon pressure from inlet tank pressure down to a regulated pressure of nominally 2.2 bar at the outlet (the set point can be changed by telecommand). The inlet pressure is at 186 bar maximum (BOL at 50°C) and decrease down to less than 3 bar (EOL at 20°C and density 16.44 kg/m3 corresponding to 1% unused propellant mass).
- To guarantee a total Xenon mass throughput of 250 kg without exceeding the solenoid valves 1 million cycles qualification limit.
- To ensure that the Xenon remains in a gaseous state throughout the passage from the High Pressure Node to the Low Pressure Node. In other words, the Xenon temperature has to be maintained between 20 ºC and 50 ºC.
- To provide the necessary input-output ports to fill and drain the Xenon Tanks.
- To provide Telecommands/Telemetry interface functions to the S/C by a dedicated MIL-STD-1553B interface (Tanks pressure is measured through the PSA).
- To provide self health checks of the equipment and to enable diagnosis by manual operation.

The pressure regulation is performed by controlling two solenoid valves using a Bang-Bang Logic (BB). The BB logic can be summarized as the following: when the pressure in the low pressure node of the PSA (LPN) decreases below the programmable pressure set-point (typically 2.2 bar), the system is triggered. The upstream valve is opened to fill the internal cavity between the two valves, for a time T1. The upstream valve is then closed, and the two valves stay closed for a period T2. The downstream valve is finally opened for a T3 opening time, in order to release the stored mass and fill the downstream volume. Simultaneous opening is not permitted by design of the driving electronics, feature that adds safety to the system.

The BB logic described above requires two (2) solenoid valves in series to be implemented. The PSA extended the concept to three (3) solenoid valves: at any time, one valve is acting as isolation valve, while the other two are performing the BB operations. This design choice opens to different operational scenarios represented in Figure 1.

By operating with one or two cavities, and furthermore with the upstream or downstream cavity when operating with one cavity only, it has been possible to comply with the different mass flow requirements (10 mg/s Xe for the EP mode, and 200 mg/s Xe for the CGT mode), and also to implement duty cycle strategy for the solenoid valves in order to reduce the total number of actuations per valve.

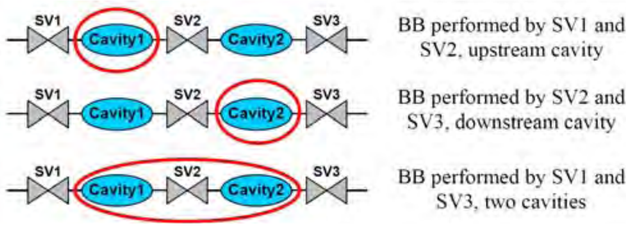

Figure 1: BB Operational Scenarios with 3 Solenoid Valves in line

The valve timing is part of the control logic, and is changed during the PSA life (i.e. upstream Xenon density) and according to the downstream user (i.e. the requested mass flow). The PSA Hardware is delivered with a dedicated EcosimPro Deck [4], which provides the best valve timing in order to obtain the required pressure regulation minimizing the number of valves actuation.

SGEO PSA PRP Overview

The Pressure Regulator Panel (PRP) is the thermo-fluidic part of the PSA. The PRP is schematically depicted in Figure 2: the nominal and redundant elements are highlighted, together with the fluidic connections to the system. For a detailed description of the PRP see [3]. The PRP is 100% welded (Titanium and Stainless Steel).

The PSA PRP model philosophy followed in the SGEO program has been the manufacturing and testing of tree models: the PRP Structural and Thermal Model (STM), the PRP Engineering Model (EM), depicted in Figure 3, and the PRP Proto-flight Model (PFM), depicted in Figure 4.

The PRP EM is identical to the PRP PFM, except for the presence of the nominal branch components only, which are flight-grade. Stainless Steel dummies are replacing the missing components.

Key performances and main budgets of the PRP PFM are reported in Table 1.

SGEO PSA SCE Overview

The SCE unit is made of two identical nominal and redundant modules (SCE Module1 and SCE Module2), interfacing respectively with the nominal and redundant actuators and sensors of the PSA PRP.

Each SCE module is connected to the spacecraft primary power bus through a dedicated Latching Current Limiter (LCL). Each SCE module is set ON and OFF through dedicated telecommands sent by the spacecraft and provides a direct ON/OFF status, a direct telemetry of the current on the primary power bus (excluding the consumption of the heater).

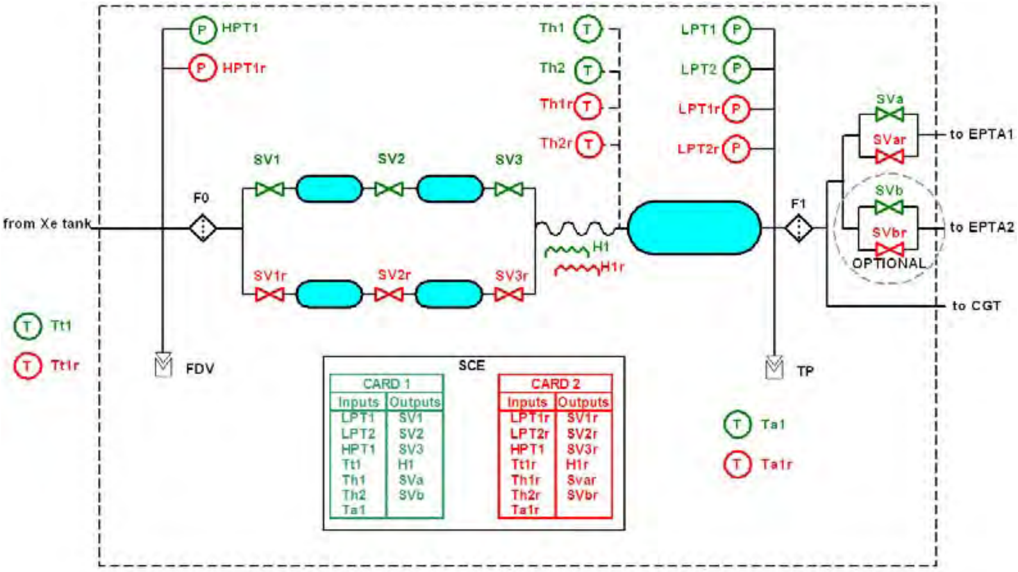

Figure 2: PSA PRP PFM Fluidic Diagram

Figure 3: PSA PRP EM

Figure 4: PSA PRP PFM

Table 1: PRP PFM Main Requirements	
Mass	4.5 kg
Envelope (WxLxH)	480x373x123 mm
Upstream Pressure (HP)	MEOP 186 bar Proof pressure 285 bar (1.5 times MEOP)
Downstream Pressure	Programmable set-point up to 5 bar Nominal Precision (programmable): ±5% EP mode, +5% -20% CGT mode
Maximum mass flow (Xe)	Up to 200 mg/s
Average Power Consumption (Only PRP)(1)	Standby = 1 W EP Mode = 10 W CGT Mode = 10 W + 13 W of Xe heating power (only at BOL)
Temperature	Operative/Startup: +20ºC/+50ºC Non-operative: -25ºC/60ºC
Hydraulic I/F	Tank and FDV: ¼''x0.71 mm Ti Test port and EPTA1/2/CGT outlets: ¼''x0.41 mm Ti
Electrical I/F	Pigtail with 4 25 pins connectors - 1 for Nominal Power lines - 1 for Nominal Signal lines - 1 for Redundant Power lines - 1 for Redundant Signal lines
Mechanical I/F	16 M4 bolts
Working Fluids	Xenon
Mission total mass throughput	>250 kg
Internal Leakage @186 bar	< 1e-4 He ssc/s (measured value 1e-6 He ssc/s)
External Leakage @ 186 bar	< 1e-6 He ssc/s (measured value 1e-8 He ssc/s)
Life	15 years

(1) Power Consumption is total power that the PRP requires to the SCE. Dissipation indicated the power used by the components. The difference between Consumption and Dissipation corresponds to the power transmitted to the working fluid.

Table 2: SCE PFM Main Interface Requirements	
Mass	2.6 kg
Envelope (WxLxH)	225x210x80 mm
Average Power Consumption (Only PRP)	Standby = 3.5 W EP/CGT modes = 4 W
Temperature	Operative/Startup: +20ºC/+50ºC Non-operative: -25ºC/60ºC
Electrical I/F (each SCE module)	- 25 Pins Signal lines Connector (to PRP components) - 25 Pins Power Lines Connector (to PRP components) - 15 Pins MIL-STD-1553B-RT address connector (to to S/C) - 9 Pins MIL-STD-1553B -bus connector (to to S/C) - 26 Pins SCE ON/OFF & TC/TM and external TM Connector (to S/C) - 9 Pins Primary Power Bus Connector to (S/C)
Mechanical I/F	6 M4 bolts

Each SCE module interfaces with the spacecraft nominal and redundant (A and B) MIL-STD-1553B buses and responds to a specific RT address, whose value is fixed by a set of strapping on a J11/J21 external connector.

Each SCE module is functionally and electrically independent, no electrical cross-strapping is done between both modules. For a detailed description of the PSA SCE see [3].

The PSA SCE Model Philosophy followed in the SGEO program has been of one Structural and Thermal Model (STM), one Engineering Model (EM), one Engineer Qualification Model (EQM) and one Proto-flight model (PFM), depicted in Figure 5. The main SCE physical characteristics are reported in Table 2.

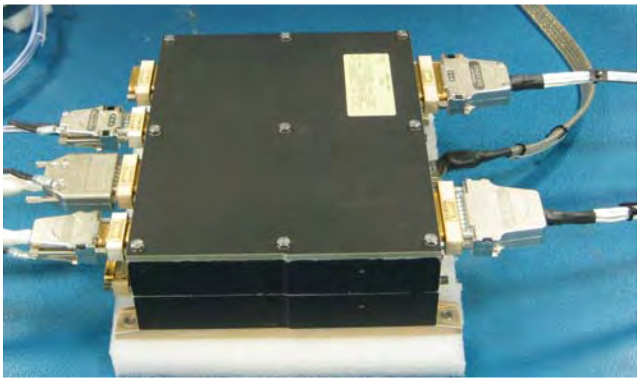

Figure 5: PSA SCE PFM

SGEO PRP EM FUNCTIONAL TEST SETUP

The functional test setup and results presented in this paper are related to the PRP EM and SCE EM functional testing. PSA PFM functional testing has been successfully concluded in April 2012, but it's not presented in this paper.

The EM Functional testing was performed using Xenon grade 5.0 in vacuum conditions (except for tests EP9 and CGT7, which were performed in altitude chamber due to schedule constraints). The test setup is schematically reported in Figure 7, in both its electrical and hydraulic parts.

TEST SETUP DESCRIPTION: FLUIDIC PART

As reported in Figure 7, the Xenon 5.0 cylinder, loaded at the beginning at around 2.000 kg/m^3 (130 bar @20ºC), is placed in a climatic chamber, and used throughout the test in a blow-down configuration. The upstream Xenon pressure is controlled by changing the chamber temperature. The Xenon bottle is connected to the ground support equipment named "Pressurization Panel" (PP), depicted in Figure 6.

The PP is made of two parts, one high pressure side which feeds the PRP and one low pressure side which acts as PRP downstream boundary conditions, and it performs furthermore the following functions:

- To implement safety device to protect personnel and the downstream hardware;
- To provide, for each side, two independent pressure readings (one analogical and one digital) and one temperature reading (digital);
- To provide manual control valves;
- To filter the working fluid upstream the equipment under testing;
- To implement different calibrated orifices in the low pressure side, in order to reproduce three nominal mass flows @2.2 bar: 10 mg/s, 25 mg/s and 200 mg/s. Orifice calibration was successfully crosschecked also by installing calibrated flow-meters, courtesy of ESA.
- To provide external fluidic port for line purging/vacuum.

Figure 6: Picture of the Pressurization Panel (PP)

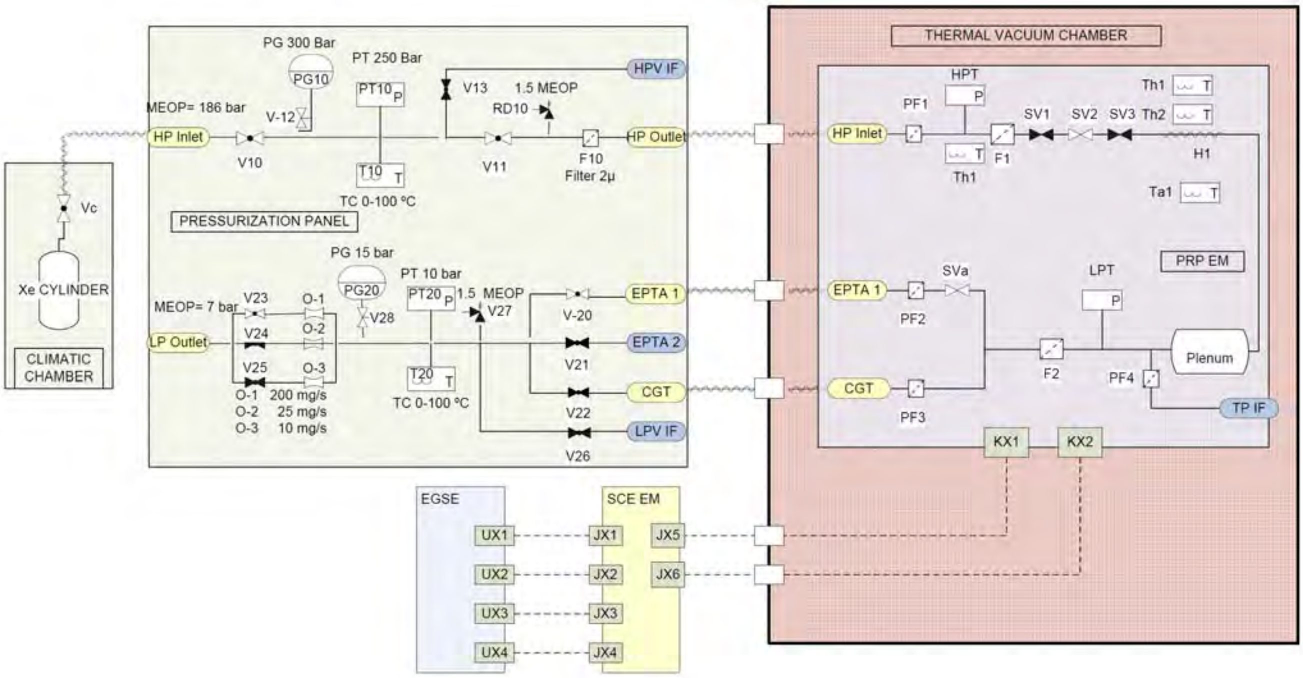

Figure 7: PSA EM Functional Test Setup

TEST SETUP DESCRIPTION: ELECTRICAL GROUND SUPPORT EQUIPMENT

The PSA PRP EM is powered and controlled by the SCE EM, through a dedicated ground testing harness; the PSA SCE EM is configured and operated by an Electrical Ground Support Equipment (EGSE).

The EGSE is packed into a 19"/26U Cabinet, and performs the following functions:

- To provide a main power supply to the equipments
- To provide a Labview based interface software, which permits a full interaction with the SCE through MIL 1553: to configuring the SCE parameters, to select and execute the SCE operation mode, to record the SCE telemetry and to execute test sequences.
- To provide a dedicated static load simulator to reproduce the PRP behavior during the SCE only testing.

SGEO PSA EM FUNCTIONAL TEST LIST - EP MODE

The Electric Propulsion Mode Functional test campaign presented hereafter covers a total of 18 runs, divided in 8 runs in "cold conditions", i.e. the PRP Thermal Reference Point (TRP) is @ 20ºC, and 10 runs in "hot conditions", i.e. TRP @ 50ºC. Table 3 and Table 4 report the detailed test list for the EP Mode.

Test conditions were selected in order to cover, at the maximum requested Xenon mass flow (10 mg/s), the MEOP, Mid Life and EOL Pressure conditions. Different cavities configurations were also tested: upstream or downstream cavity when only one cavity is used; and both one and two cavities at 60 bar.

Working fluid was Xenon 5.0 for all tests, and all tests were performed in vacuum except for test ID *EP9*, which was performed in an altitude chamber.

"Trigger Plenum Pressure" column in Table 3 and Table 4 indicates the pressure reading threshold set to trigger the BB actuation.

Table 3: EP Mode, 20ºC "Cold Testing"

#	Test Name	HPN [bar]	Trigger Plenum P [bar]	Mflow [mg/s]	Duration [s]	Cavities
EP1	EP-93-C-1U	93	2.11	10	600	1, Upstr.
EP2	EP-70-C-1D	70	2.11	10	600	1, Downs.
EP3	EP-60-C-1D	60	2.11	10	600	1, Downs.
EP4	EP-60-C-2	60	2.11	10	600	2
EP5	EP-45-C-2	45	2.11	10	600	2
EP6	EP-30-C-2	30	2.11	10	600	2
EP7	EP-10-C-2	10	2.11	10	600	2
EP8	EP-4-C-2	4	2.11	10	P < 2.4 bar	2

Table 4: EP Mode, 50ºC "Hot Testing"

#	Test Name	HPN [bar]	Trigger Plenum P [bar]	Mflow [mg/s]	Duration [s]	Cavities
EP9*	EP-186-H-1	186	2.11	10	600	2
EP10	EP-135-H-1U	135	2.11	10	600	1, Upstr.
EP11	EP-93-H-1U	93	2.11	10	600	1, Upstr.
EP12	EP-70-H-1D	70	2.11	10	600	1, Downs.
EP13	EP-60-H-1D	60	2.11	10	600	1, Downs.
EP14	EP-60-H-2	60	2.11	10	600	2
EP15	EP-45-H-2	45	2.11	10	600	2
EP16	EP-30-H-2	30	2.11	10	600	2
EP17	EP-10-H-2	10	2.11	10	600	2
EP18	EP-4-H-2	4	2.11	10	P < 2.4 bar	2

SGEO PSA EM FUNCTIONAL TEST LIST - CGT MODE

The Cold Gas Thrusters Mode Functional test campaign covers a total of 14 runs, divided in 6 “cold conditions” runs and 8 “hot conditions” runs.

Just like for the EP mode testing, several upstream pressure were tested using Xenon; CGT mode is always set on 2 cavities. Two EOL pressure conditions can be found for the CGT mode, one at 60 bar and 200 mg/s, and the other at less than 6 bar and 25 mg/s. Table 5 and Table 6 report a detailed list of the test cases performed.

Different triggering values were used during CGT tests.

All tests were performed in vacuum conditions, except for run *CGT7*, which were performed in an altitude chamber.

Table 5: CGT Mode, 20ºC "Cold Testing"

#	Test Name	HPN [bar]	Trigger Plenum P [bar]	Mflow [mg/s]	Duration [s]	Cavities
CGT1	CGTC-93-C-2	93	1.95	200	600	2
CGT2	CGTC-70-C-2	70	1.95	200	600	2
CGT3	CGTC-60-C-2	60	2.15	200	P < 54 bar	2
CGT4	CGTC-45-C-2	45	2.15	25	600	2
CGT5	CGTC-30-C-2	30	2.15	25	600	2
CGT6	CGTC-10-C-2	10	2.15	25	P < 4 bar	2

Table 6: CGT Mode, 50ºC "Hot Testing"

#	Test Name	HPN [bar]	Trigger Plenum P [bar]	Mflow [mg/s]	Duration [s]	Cavities
CGT7*	CGTC-186-H-2	186	2.10	200	600	2
CGT8	CGTC-135-H-2	135	2.15	200	600	2
CGT9	CGTC-93-H-2	93	2.15	200	600	2
CGT10	CGTC-70-H-2	70	2.15	200	600	2
CGT11	CGTC-60-H-2	60	2.15	200	P < 54 bar	2
CGT12	CGTC-45-H-2	45	2.15	25	600	2
CGT13	CGTC-30-H-2	30	2.15	25	600	2
CGT14	CGTC-10-H-2	100	2.15	25	P < 4 bar	2

TEST RESULTS POST PROCESSING CRITERIA

Figure 8 reports a typical downstream pressure response as read by the low pressure PRP transducers.

For each test run, three main parameters are observed, also highlighted in Figure 8:

1) *Time_BB*: time between two actuations, measured in seconds;
2) *Max Pressure Peak*: maximum downstream pressure value reached during one actuation, measured in bar;
3) *Min Pressure Peak*: minimum downstream pressure value reached during one actuation, measured in bar.

These three parameters are obtained for each BB actuation, so each run is summarized by an average value and a standard deviation (the first 2/3 BB are usually discarded to remove transient effects). These values are then compared directly with the values predicted by the PRP EcosimPro Model.

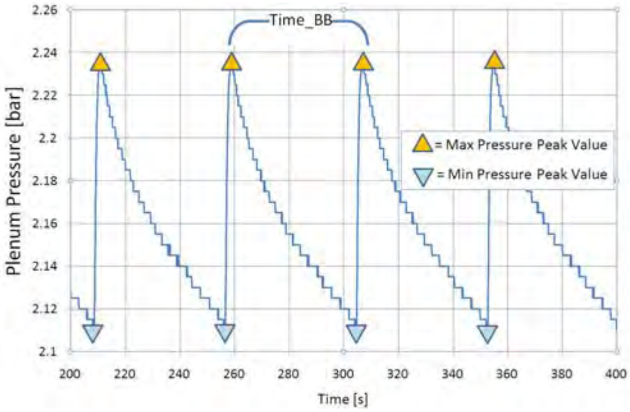

Figure 8: Typical Plenum Pressure Response and key parameters description

EOL runs (i.e. *EP8, EP18, CGT3, CGT6, CGT11* and *CGT14*), are not included in the performance parameter analysis because the upstream conditions do not allow repetitive downstream conditions; these EOL runs will be analyzed in a dedicated paragraph.

The PRP EcosimPro Schematic used for the test results simulation, built using the ESPSS library [5], is depicted in Figure 9. The “As Built” PRP components data were used to set the EcosimPro components properties, and the boundary conditions recorded during testing were used also as boundary conditions in the EcosimPro model experiments (i.e. upstream pressures and PRP thermal reference point temperature).

TEST RESULTS: EP MODE

Figure 10 and Figure 12 report the EP Mode Max/Min Pressures average data for the 20ºC and 50ºC runs, listed in Table 3 and Table 4. Standard deviations are not depicted because nearly zero. The SGEO Program specific acceptance pressure criteria of 2.2 ± 5% bar is also marked.

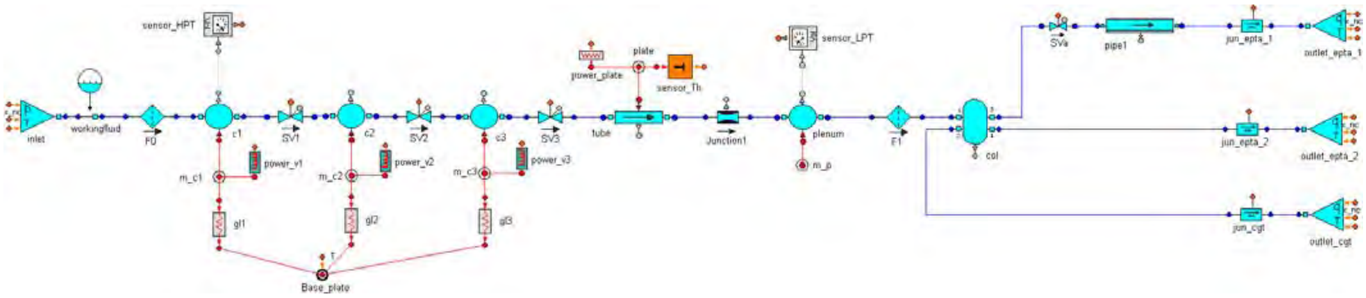

Figure 9: PSA PRP EcosimPro Schematic

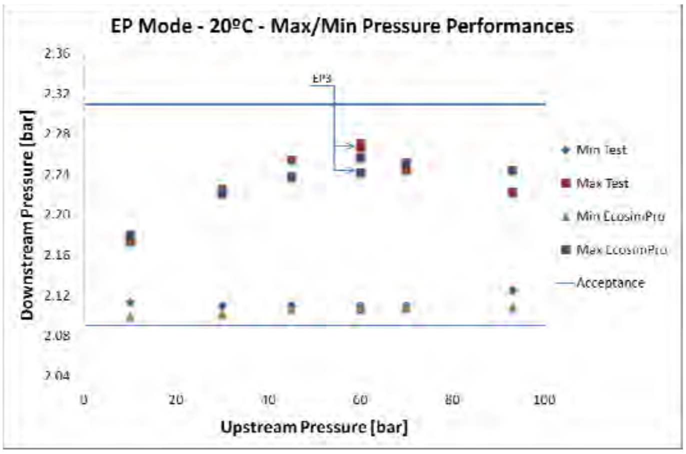

Figure 10

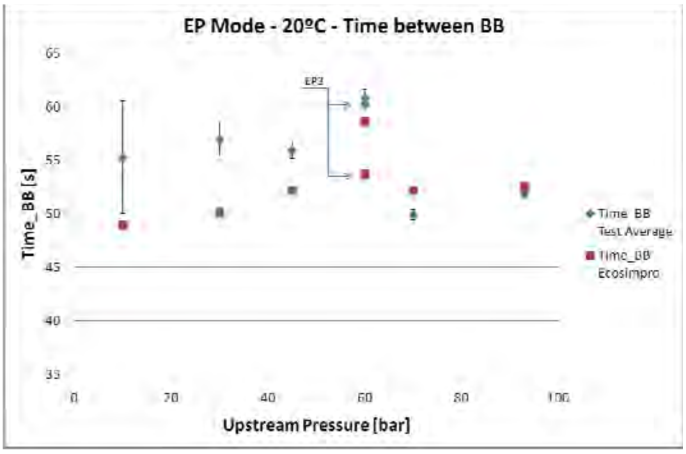

Figure 11

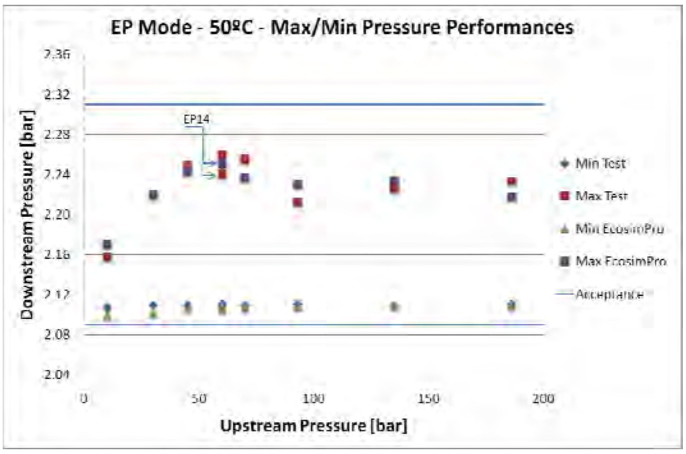

Figure 12

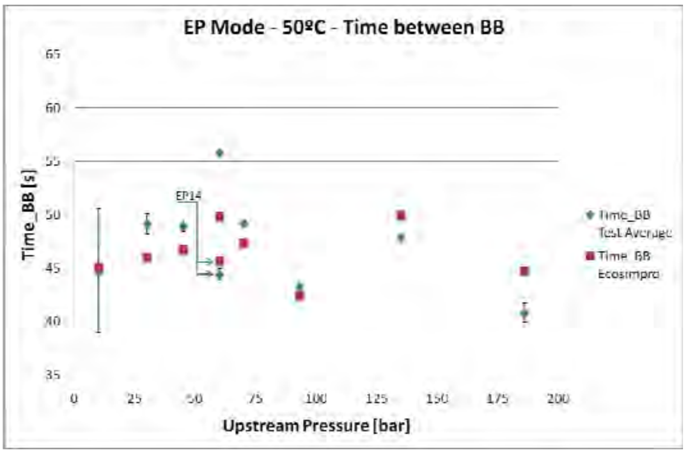

Figure 13

The match between test results and EcosimPro predictions is excellent, which is in the worst case within 1% of the measured value (which corresponds to an error of 0.02 bar).

Of particular interest is the comparison of tests *EP3/EP4* for the 20ºC set and *EP13/EP14* for the 50ºC set. The aim of these four tests is to check the PRP performances using one or two cavity at the same upstream pressure of 60 bar. It can be concluded that the system can deliver the expected pressure increase despite the cavities configuration.

It is observed that the full pressure increase allowed (2.2 ± 5% bar) is not entirely covered. This result is the sum of two effects:

1) The test setup downstream volume was underestimated, and for this reason a lower pressure rise was obtained during testing. Please observe that the EcosimPro results presented in this paper have been corrected with the actual test setup values.
2) Since the BB pressure regulation approach works with a fixed volume between valves, there exist an input density limit below which by one BB actuation is not possible to reach the maximum allowed delta pressure. This effect is observable in Figure 10 and Figure 12 for upstream pressure below 60 bar. Below this density threshold, the pressure regulator will then narrow the pressure oscillation above the triggering pressure level.

Figure 11 and Figure 13 report the performance parameter Time_BB as a function of the upstream pressure. Besides average values, standard deviations are also displayed for the test data.

In this case, the match between test results and EcosimPro predictions is very good, even if it reaches a mismatch of the 13% in the worst case. It's worth noticing that the difference between test and predicted results increases at lower upstream pressures, with also an increase in the standard deviations of the test data.

The first effect is explained as a difference on the outlet mass-flow boundary conditions between the test setup and the EcosimPro model. The mass-flow is imposed downstream the PRP by a calibrated orifice, which gives the requested 10 mg/s @20ºC and 2.2 bar. The actual mass-flow will be then a function of the downstream pressure, while the EcosimPro model imposes a constant mass-flow boundary condition. As already mentioned, the BB logic narrows the pressure oscillations towards the triggering pressure value as the upstream pressure below 60 bar, to a value that during EP testing was around 2.11 bar (Table 3 and Table 4 and Figure 10 and Figure 12). The calibrated orifice will then discharge less mass flow, rising the period between actuations. This interpretation has not been crosschecked yet by modelling the actual test setup in the EcosimPro schematic.

Regarding the increasing of the standard deviations when approaching low pressures, the explanation is linked to the test setup upstream boundary conditions. As a time optimization strategy during testing, the dead volume between the Xe bottle and the PRP (i.e. the Pressurization Panel tubing plus flexible houses volumes) was use to set the desired upstream pressure conditions whenever the Xe bottle was at higher pressure than the requested. This strategy was implemented only during EP testing, which required small mass flows. The drawback of this technique is that the upstream pressure slightly drops during the test, inducing a variation of the downstream values and eventually a higher standard deviation of the performances parameters.

TEST RESULTS: CGT MODE

Figure 14 and Figure 16 present the CGT Mode Max/Min Pressures average data for the 20ºC and 50ºC runs, listed in Table 5 and Table 6. The SGEO Program specific acceptance pressure criteria of 2.2 + 5% -20% bar is also marked.

The correspondence between test data and EcosimPro predicted values is excellent, and the difference never exceeds the 1% with respect to test data.

It can be observed again how the pressure control gets finer with the lowering of the upstream pressure, as described in the EP results as a typical Bang Bang performance characteristic.

As for the EP testing, also the CGT results are not entirely covering the permitted downstream pressure range of 2.2 + 5% -20% bar. This is due to an upper level system requirement of having a constant timing setting for the CGT during the entire mission, which imposed a trade off of the valves opening times to comply under all Pressure and Temperature conditions.

Figure 15 and Figure 17 report the performance parameter Time_BB as a function of the upstream pressure. EcosimPro and test data matching is also very good, with a relative error of the 17% in the worst case, but generally below the 10%.

It's worth mentioning that, for the CGT runs, the downstream pressure triggering value was adjusted during tests to be closer to the 2.2 bar, assuring the full 200 mg/s Xe mass flow downstream the Pressurization Panel. Furthermore, the upstream pressure conditions were always set by using the Xe bottle, keeping the upstream conditions steady during the test. As a consequence, EcosimPro/test data matching for the Time_BB parameter in CGT runs are better than the EP ones, with almost a negligible standard deviation.

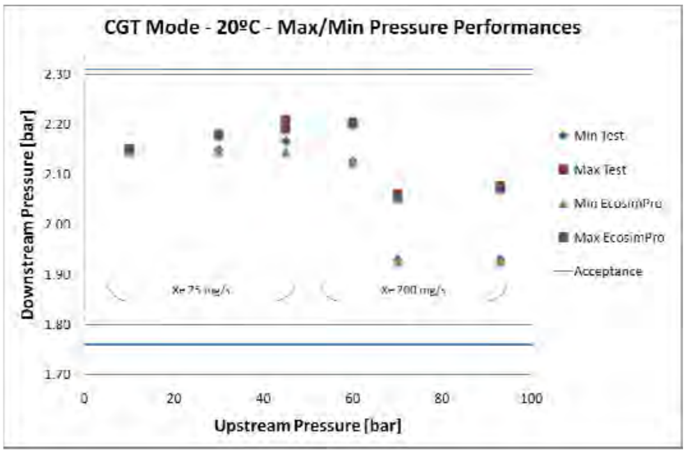

Figure 14

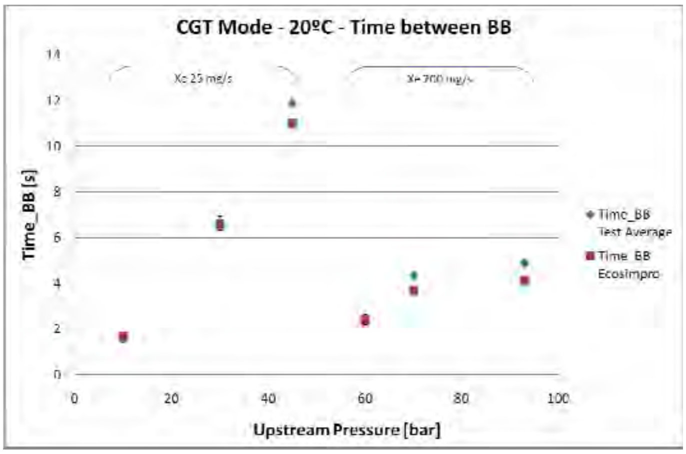

Figure 15

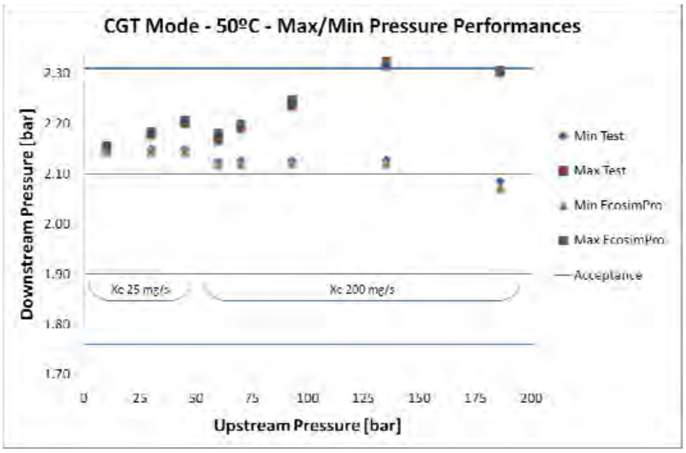

Figure 16

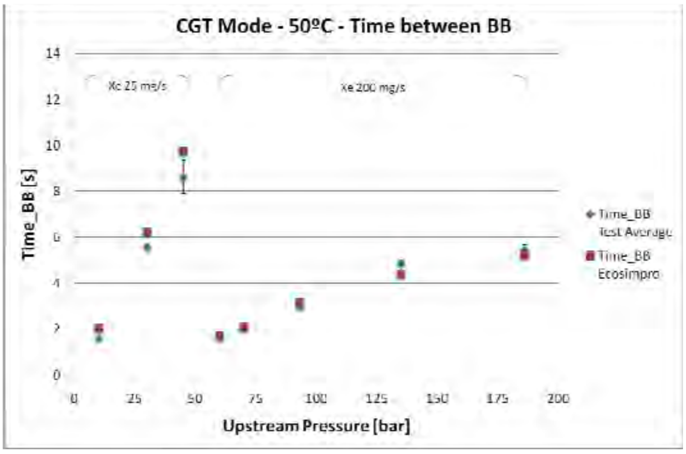

Figure 17

END OF LIFE PERFORMANCES

Test runs *EP8, EP13, CGT3, CGT6, CGT11* and *CGT14* are aimed to the measurement of the minimum upstream pressure value needed by the PRP to withstand the downstream set-point pressure at the requested Xenon mass flow. Figure 18 gives a graphical example of how this limit pressure value is derived for EP 8 test run.

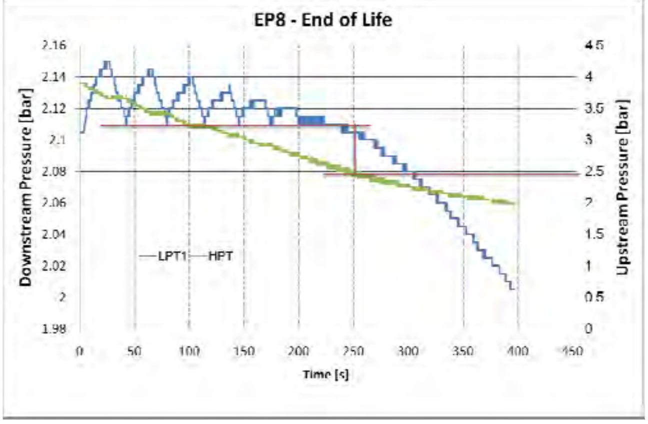

Figure 18: EP8 End of Life detail

Table 7 reports a summary of the EOL test runs, highlighting the minimum pressure drop requested to provide the indicated Xenon mass flow.

Table 7: EOL Minimum ΔP Summary

#	Test Description	Mflow [mg/s]	Upstream P [bar]	Downstream P [bar]	Min. ΔP [bar]
EP8	EP @ 20ºC	10	2.50	2.11	**0.39**
EP18	EP @ 50ºC	10	2.80	2.11	**0.69**
CGT3*	CGT @20ºC High Flow	200	40.45*	2.15	**38.30***
CGT6	CGT @50ºC High Flow	200	40.45	2.15	**38.30**
CGT11	CGT @20ºC Low Flow	25	4.65	2.15	**2.50**
CGT14	CGT @50ºC Low Flow	25	5.30	2.15	**3.15**

(*) Test CGT3 ended at 42 bar upstream without reaching the upstream pressure limit. Same results of CGT6 are indicated, but better performances shall be expected.

CONCLUSIONS

The PSA EM functional test campaign was presented and analyzed according to the main performance parameters “downstream pressure” and “period of actuation” as a function of the upstream pressure. Testing was performed under representative flight conditions and using Xenon 5.0, for the two operational modes “EP” and “CGT”.

The test results presented demonstrate high correlation with the EcosimPro model predictions, and though a compliance with the foreseen performances. The PRP can supply Xenon at the requested downstream pressure under the entire tested pressure and temperature domain, for both typical EP and CGT mass flows. The Maximum Operating Pressure tested was 186 bar, and the maximum mass flow delivered during testing was 200 mg/s.

The measured minimum upstream pressure as a function of the mass flow and the thermal reference point temperature is also reported in this paper.

The pressure drops obtained indicate that the PSA can significantly minimizing the propellants tank residuals while being still fully delivering the required mass flow. Beyond this point, the PSA could be run indefinitely leaving the propellant tanks completely passivated, meeting the Satellite End of Life guidelines indicated in ESA’s Space Debris Mitigation Policy [6].

The PFM performance test campaign, concluded in April 2012 and not presented in this paper, confirms the EM results.

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