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Development of a Xenon Flow Controller for the PPS®5000 Hall Thruster Unit

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I. Introduction

Electric Propulsion (EP) devices have been under research and development at Safran since the late 1960's. Since the late 1990's, Safran has concentrated on Hall Effect Thruster technology, successfully conducting three thruster qualification programs to date, and delivering EP hardware to 12 different GEO satellites over six different platforms in addition to the *Smart-1* lunar exploration probe.
The current Hall thruster product line includes four thrusters, at different stages of maturity: first, the flight-proven PPS®1350 thruster unit (thruster and XFC) and its three versions (–G, –S and –E). Next, at both ends of the power and thrust range, two thrusters are at the Technology Demonstrator stage, one for low power applications (200-700 W), and the other for high power applications (20 kW). Finally, the PPS®5000 is a 5-kW-class Hall thruster unit (thruster and XFC) currently under development and qualification, with firm orders for the production of flight models. This paper will describe the current development and qualification status of the Xenon Flow Controller of the PPS®5000 program.
The PPS®5000 Hall Thruster Unit is a propulsion system comprising a Hall Thruster and its Xenon Flow Controller (XFC), as represented in Figure 1 and Figure 2.

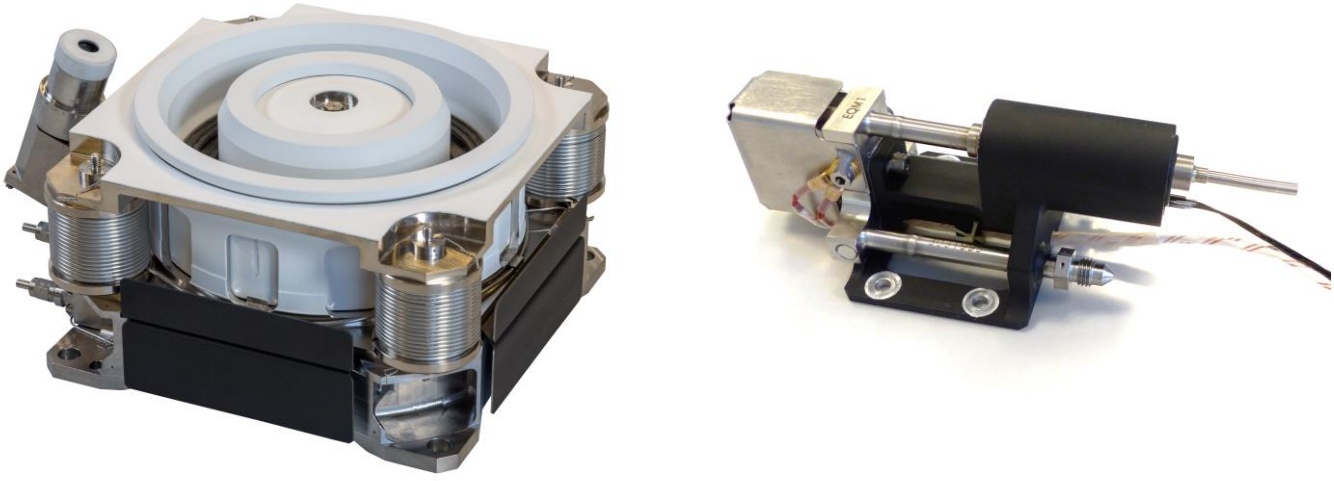

Figure 1 – The PPS®5000 Hall Thruster Unit: thruster (left); and XFC (right).

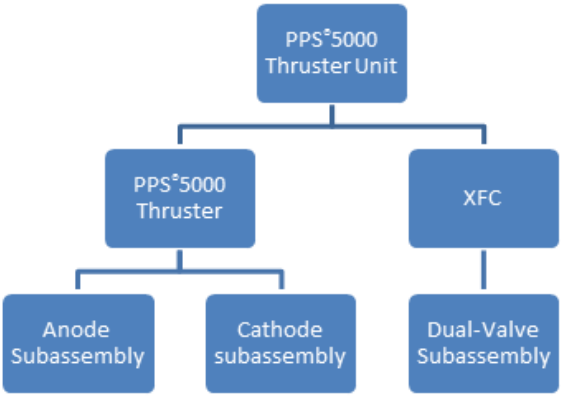

Figure 2 – PPS®5000 Thruster Unit product tree.

II. XFC Design

Taking benefit from the heritage of the XFC of the PPS®1350, the PPS®5000's XFC has the objective of improving the design. That is why the XFC-5000, in comparison to the XFC-1350, is able to propose:

- an enlarged flowrate range,
- under a widest temperature range,
- the same robustness to mechanical stress
- a lower mass
- a lower manufacturing cost

The XFC has been designed in order to get the widest flowrate range and minimizing its global mass. An aggressive design-to-manufacture approach also led to thoroughly revisit its general architecture. Indeed, up to 40% of reducing cost was reached from the 1350-extended-to-5000 targeted recurring cost. This was reached thanks to design simplification like making all the welding joints common, or optimizing the number of valves with regard to real needs for a thruster equipped with a single cathode. The mass was also reduced by more than 20% compared to the XFC 1350.

The XFC consists in: a filter plus two valves in series authorizing the xenon flow, a thermothrottle for flowrate regulation purpose and two flow restrictors in order to dispatch the flow between both thruster anode and cathode with appropriate ratio.

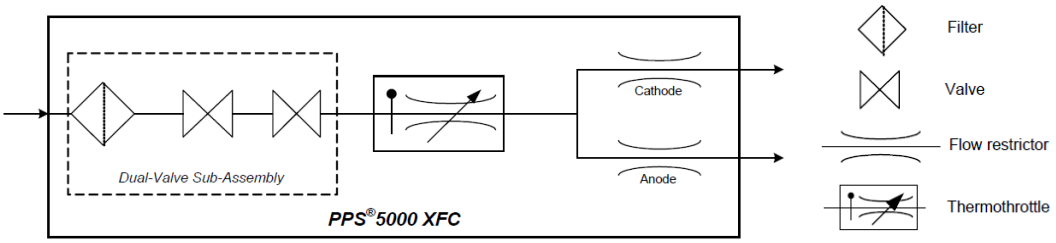

Figure 3 - XFC Functional Scheme

III. Development of the XFC

In order to meet the very stringent time-to-market constraints placed on the PPS®5000, the development logic was adapted for the XFC as well as for the thruster. Thus, an overlapping of the preliminary design, development and qualification phases has occurred as described on the Figure 4.

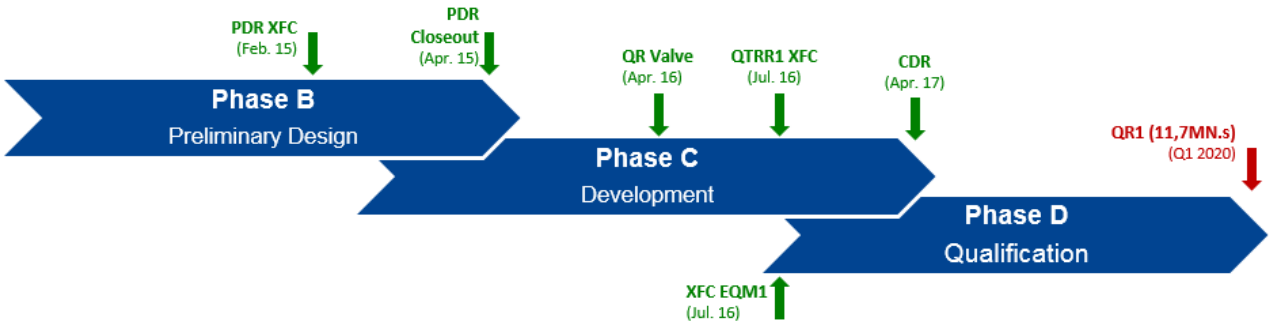

Figure 4 – XFC development logic

The development of the XFC has started with the Dual-Valve sub-assembly which has been developed and qualified independently from the XFC. Indeed, the Dual-Valve sub-assembly was submitted to functional test, envrionmental test and life test with more than 25 000 actuations under several operating conditions before being integrated at XFC level for upper level qualification purpose. The Dual-Valve qualification was pronounced in early 2016.

The XFC development was based on modeling activities backed by extensive testing. Indeed there were 9 development models (from elementary components to complete XFC) which were used during up to 15 test campaigns in total, covering functional, mechanical, system level, thermal stress tests, and so on… for the dual-valve sub-assembly and the complete XFC, covering also 8 different configurations of thermothrottle, in addition to the qualification test campaign of the XFC.

The qualification test campaign, gathering thruster and XFC, is now underway according to the Figure 5.

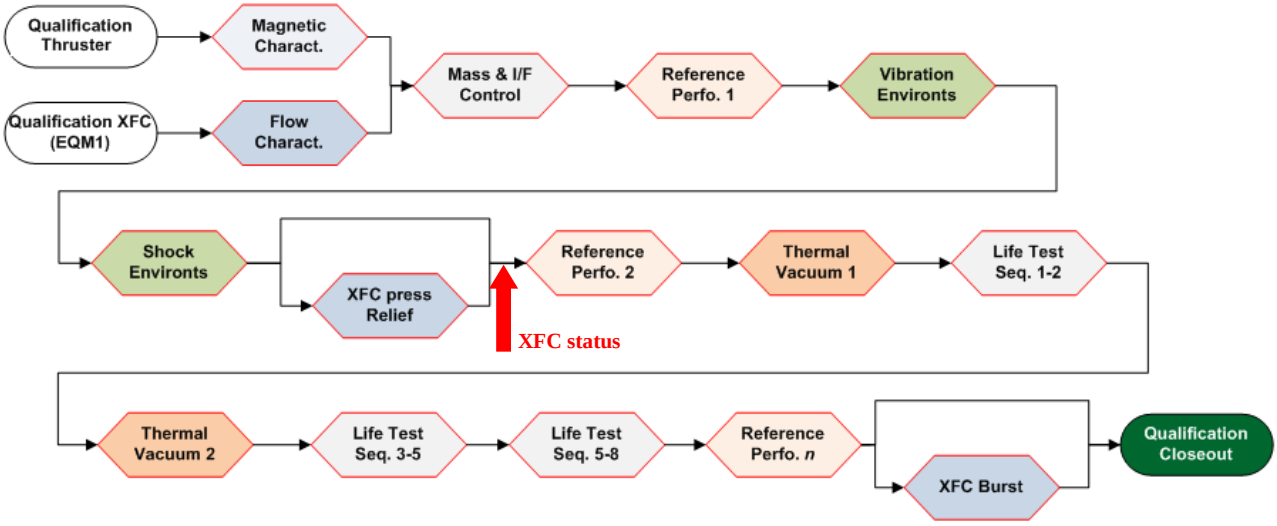

Figure 5 - Thruster Unit Qualification Test Sequence

Note that in-between each qualification sequence described in Figure 5, the XFC is submitted to several controls like visual inspection, electrical controls, internal and external leakage tests and dual-valve functional tests. All of them allow validating the qualification sequence realised just before.

IV. Qualification status of the XFC

The XFC qualification model has already successfully completed early functionnal and thermal characterization tests, as well as vibration, pyroshock and pressure relief tests.

The thermal characterization of the XFC EQM1 flowrate as a function of the thermothrottle characterization is provided on Figure 6. It can be noticed that maximum performance has been validated spending more than 900 hours beyond 90% of Itt.

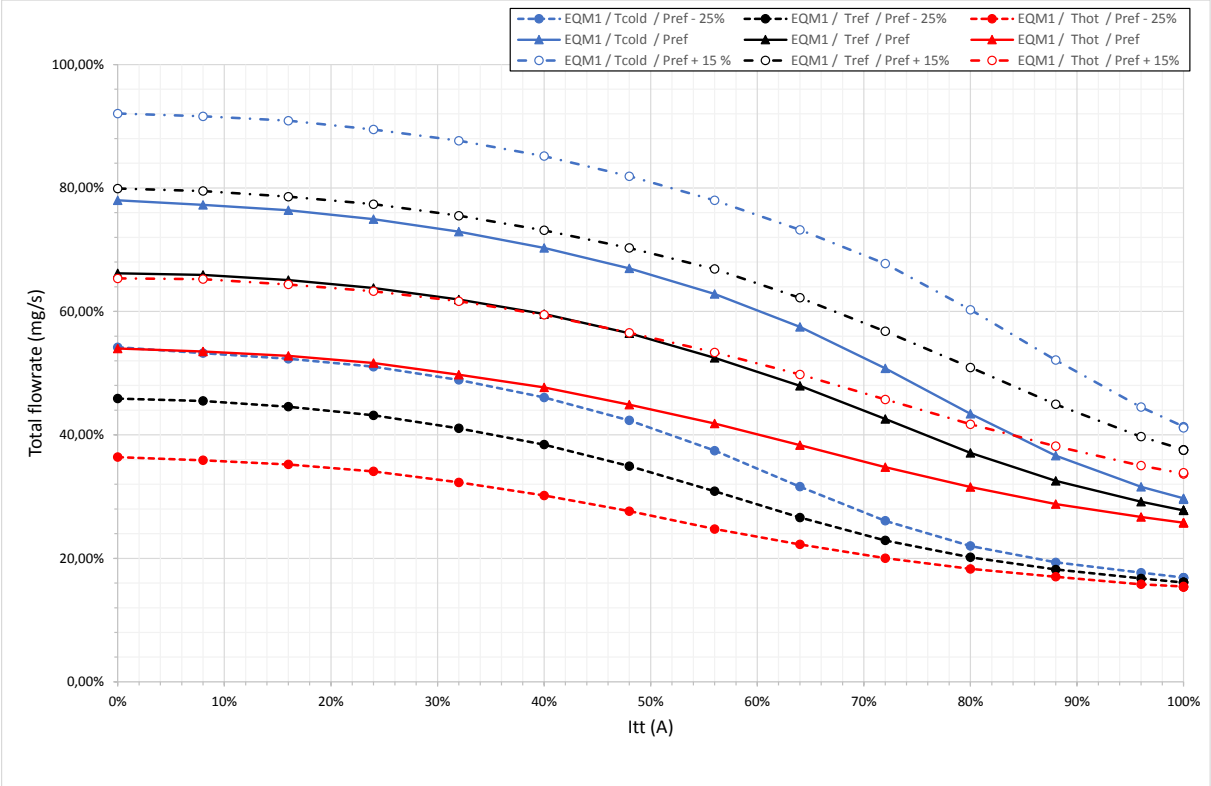

Figure 6 - XFC EQM1 Flowrate Characterization as a function of Thermothrottle Current

The vibration tests sequences allow qualifying the high level sine loads, the random vibrations loads as well as the pyroshocks.

Finally, the XFC EQM1 has proven, through the pressure relief subsequence, a total amount of :

- 1 cycle of dual-valve actuation, when submitted to 70% of MEOP over 30 min
- 100 cycles of dual-valves actuation, after being submitted to 70% of MEOP during 30 min and allowing to decrease the pressure down to 20% of MEOP bars after opening the valves.

From XFC point of view, it remains to perform the thermal cylcing, the life test and the burst test in order to claim the complete qualification of the XFC.