Pulsed Plasma Thruster Development for Small Satellites Applications in Argentina

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1. Introduction

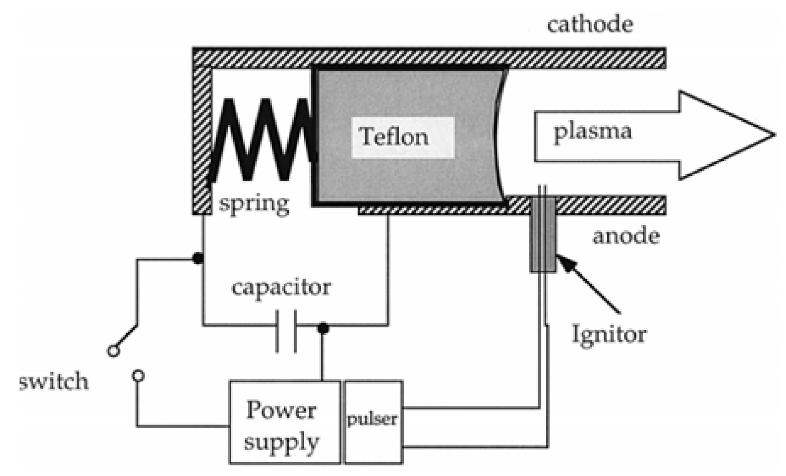
Electric propulsion is a system that increases spacecraft velocity by using electric energy as a power source to accelerate the propellant at a very high exhaust speed [1]. The propellant acceleration is performed by an electrothermal expansion and/or by electromagnetic forces applied directly over ionized particles. This kind of thrusters shows a higher specific impulse than conventional chemical thrusters, because of the more efficient propellant utilization. Electric propulsion plays an important role in modern small satellites, providing a means to perform maneuvers and allowing an efficient station keeping and attitude control with a relatively small mass.

2. Background

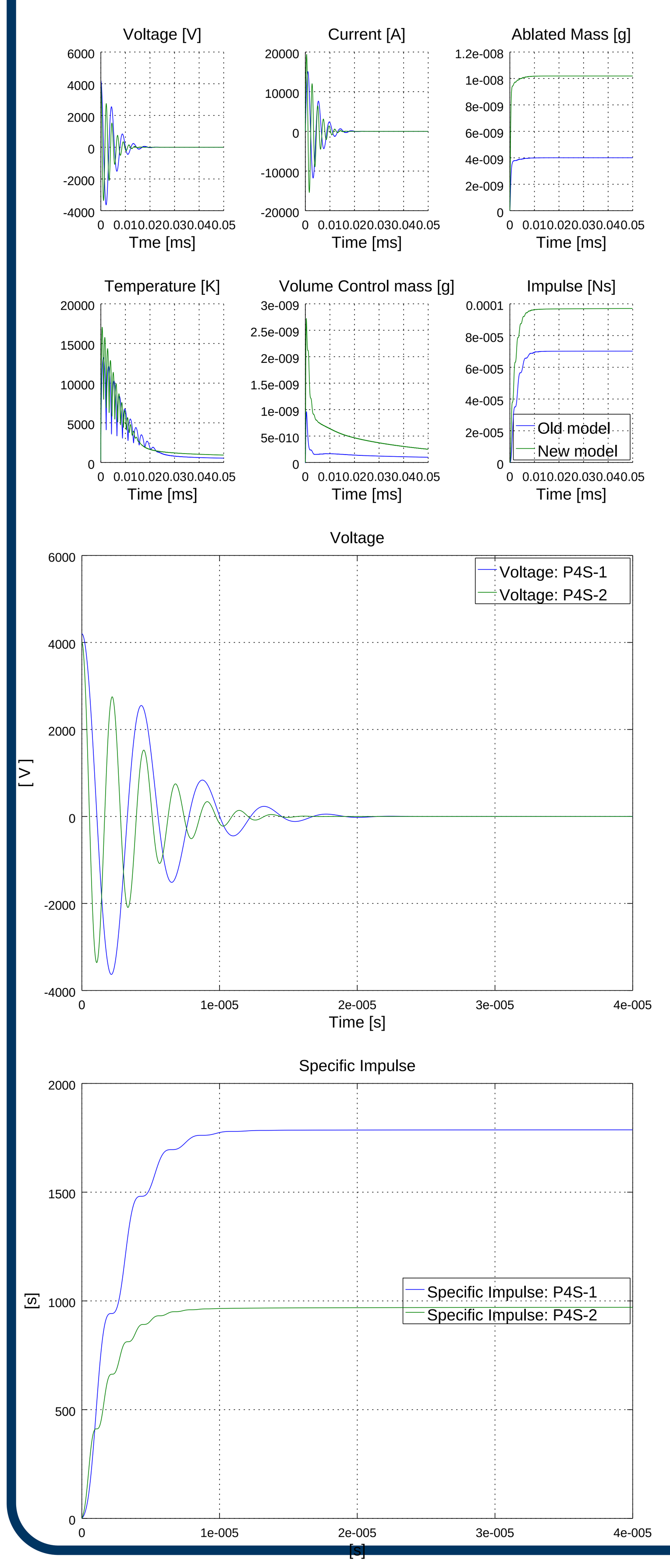
Electric propulsion research has been carried out in the Centro de Investigaciones Aplicadas –Argentina– or almost 20 years, focusing on developing a microsatellite PPT –ie. Pulsed Plasma Thruster–, in order to perform station keeping and deorbit maneuvers. The project main purpose is to obtain a qualified thruster, which can be mounted on microsatellites of approximately 30kg mass.

3. PPT concept

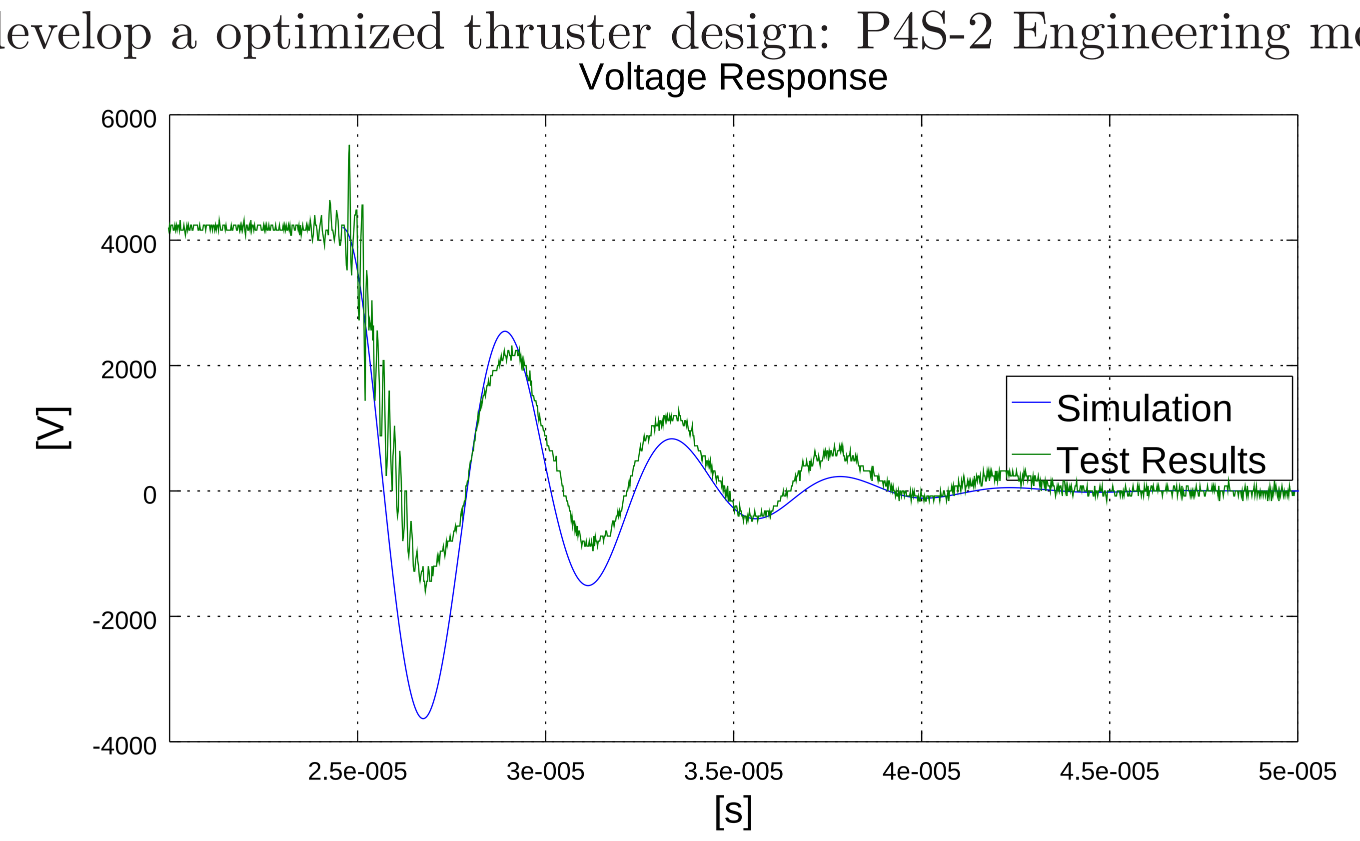
PPTs work with solid propellant, generally a bar of politetrafluoroetylen –Teflon®– placed between two electrodes [2]. Propellant is ablated by means of an electric energy discharge –stored in a capacitor–, releasing electrically charged particles which accelerate rapidly when interacting with the self induced electromagnetic field. These thrusters usually show an I_{sp} between 1000s and 2000s, and the efficiency of a flight qualified PPT is roughly 10%.



4. Modelling and Simulation



A development coaxial PPT model –mounted on a test bench– was tested within a vacuum chamber. Experimental data collected –ablated mass, bit-impulse, circuit voltage response– were useful in order to calibrate and validate a code –also developed in the CIA–, based on a PPT mathematical zero-dimensional model [3]. By using this software, it was possible to simulate several PPT cases –each one of them with different geometries and electric features–, in order to develop a optimized thruster design: P4S-2 Engineering model.



Parameter	Experimental data	Simulated data	Error
Ablated mass [Kg]	3.95e-9	3.99e-9	1%
Bit impulse [Ns]	70e-5	70.04e-5	0.06%

Table 1. Calibration results.

Case Nº	Ext. Radius [m]	Int. Radius[m]	Channel length[m]	PTFE length	Voltage [V]	Capacity [F]	Impulse I[μNs]	A. mass [μg]	Isp[s]	η
0	0.015	0.0045	0.0375	0.175	4200	2.60E-06	70.04	3.99	1788.5	2.67
12	0.015	0.003	0.025	0.0875	4000	1.80E-06	96	9.7	994	3.21

Table 2. P4S-1(case 0) vs. P4S-2(case 12) performances.

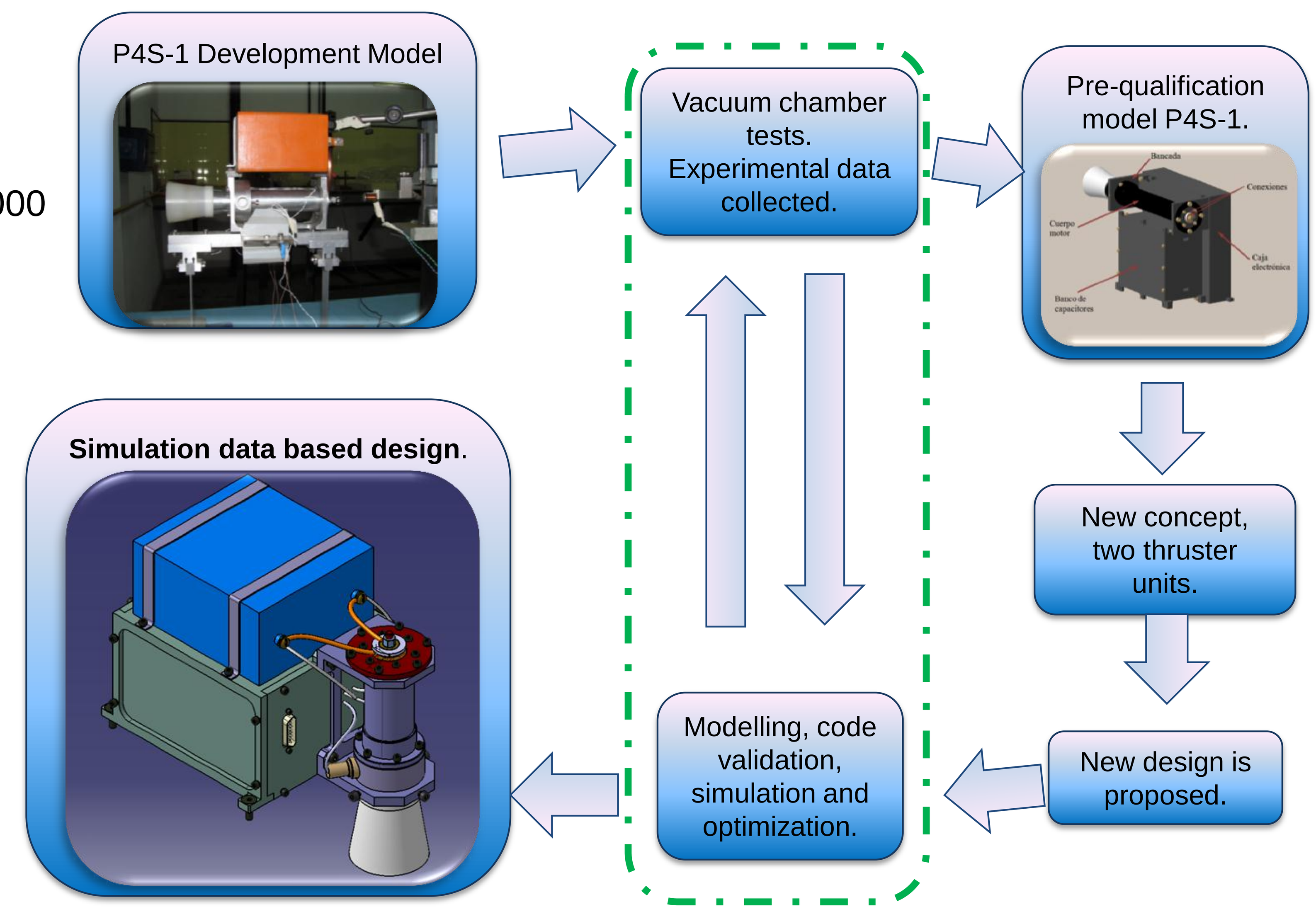
5. PPT Engineering model

A coaxial electrode development model was first designed, manufactured and mounted on a low thrust test bench. Subsequently, tests were made in a vacuum chamber, and experimental data was collected. By using a simulation code, it was possible to run several cases. Electrical and geometrical parameters were modified, resulting in a model with higher thrust and impulse, although resulting in a lower specific impulse as well. These parameters were employed to carry out an PPT mechanical design, which once manufactured, it will be tested in right time.

Requirements
- I_T = 1500 Ns
- I_{bit} =100 μNs
- Nº pulses<10.000.000

Performance (sim.)
- I_{sp} = 990 s
- I_{bit} = 96 μNs
- Pulses = 7.885.700
- Thrust = 0.28 mN
- Efficiency = 3.4%

Capacitor features
- Voltage = 4000 V
- Capacity = 1.8 μF



6. Conclusions

PPT Qualification Model is designed and its manufacturing is about to start. Testing will provide useful data, such as ablated mass per discharge, impulse per pulse, specific impulse and electric circuit response. This information can be used as a feedback for the mathematical model and code, in order to develop a more precise PPT simulation tool.

7. References

[1] R.G. Jahn. Physics of electric propulsion. (32244 T), 1968.

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[3] Vitulich C. A. Cimino A. M. Numerical analysis tool for design and optimization of a coaxial pulsed plasma thruster. ISBN 978-2-917761-46-5, 2017.

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