MPCS-2017-Mc02

Multi-Mode Micropropulsion

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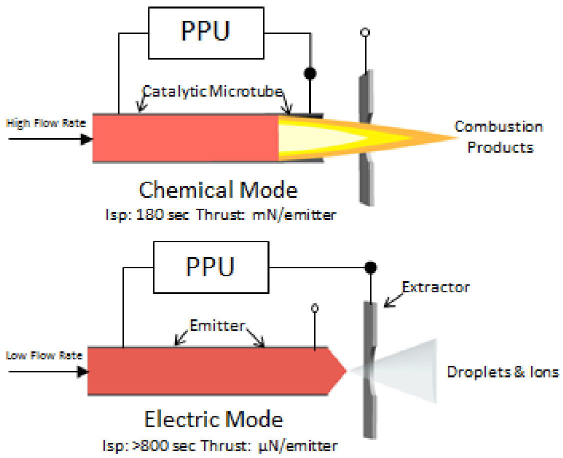

Figure 1. Multi-mode micropropulsion: a single microtube / emitter is operated as either a catalytic chemical thruster or an electrospray electric thruster.

Spacecraft have traditionally used chemical or electric propulsion as a means of orbital manuevering. Chemical propulsion is capable of rapid manueverability at the expense of fuel efficiency. Electric propulsion is the converse: very good fuel efficiency, but low thrust resulting in long trip times. Typically, due to mass or volume constraints, a single mode is selected, designed, and optimized specifically for a given mission. As mission requirements evolve during the design process, the propulsion system may have to be adjusted and, in some cases, components and systems re-qualified. This is contrary to the tenets of small satellite design where rapid turnaround is enabled through plug-and-play architecture. Over the past decade, several propulsion systems have been designed to fit the small satellite platform, namely CubeSats. However, these systems, aside from fitting in a 1U cube, have vastly different interface requirements especially in terms of power and flight software. Furthermore, these systems only offer one type of propulsion, chemical or electric, meaning the spacecraft is constrained to either type of manuever with little adaptability during the design phase let alone on-orbit.

Multi-mode spacecraft propulsion is the combination of chemical and electric propulsion in a single system with at minimum shared propellant between the two modes, and ideally shared hardware, namely tanks, valves and other feed system components. Use of a shared propellant allows for propellant budget to be allocated between modes synergistically as mission needs arise whether on-orbit or during satellite development, significantly enhancing the flexibility and capability of the spacecraft.

Missouri S&T has developed a propulsion system capable of both chemical and electric propulsion with a single propellant, tank, feed system, and thruster [1]. The system is equivalent in mass and volume to state-of-the-art single mode chemical or electric systems, but can be operated in either mode at any given time.

The thruster uses a single ionic liquid propellant based on a binary mixture of hydroxylammonium nitrate and 1-ethyl-3-methylimidazolium ethyl sulfate capable of exothermic decomposition in a monopropellant mode [2] as well as provide an efficient source of ions in an electrospray mode [3,4]. Chemical mode calculations show the thruster capable of high-thrust (> 500 mN) at a specific impulse of 180 seconds [5,6] and electrospray experiments show the thruster capable of specific impulse in excess of 1000 seconds [4].

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