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Development Project Overview for MEP Engine Propulsion System for Small Satellites

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Abstract

Ball Aerospace (Ball) and the Electric Propulsion Laboratory, Inc. (EPL) are in partnership to develop a high specific impulse electric propulsion system. The propulsion system is based on EPL's Magnetogradient Electrostatic Plasma 650-Watt (MEP 650) engine technology. The goal of the MEP 650 project is to develop a flight-like, engineering model (EM) MEP 650 system that can meet future Ball Small Satellite (SmallSat) mission requirements. These requirements are met by an engine that operates at a discharge power of 650 W in self-heating mode, attains a specific impulse of 1,500 seconds, a thrust of 29 mN, and processes about 7.0 kg of xenon propellant at full power.

To support the project efforts, two laboratory engines (EM1 and EM2), a power conditioning unit (PCS), a xenon flow system (XFS) and a MEP command, control, and telemetry (MCCT) unit have been built and tested. Laboratory engine EM1 is dedicated to endurance testing and has completed a 947-hour endurance test at 684 W, at an average discharge voltage of 258 volts. The EM2 engine is dedicated to support continued performance optimization and plasma plume investigations. EPL has completed the MEP system component design, structural and thermal testing, fabrication, and has extensively tested all components, including full system level "end-to-end" performance testing. Characterization of the EM2 engine has been conducted for discharge power levels up to 1 kW (any power level beyond 700 W requires the use of facility power supplies). The results to-date have exceeded the Ball (SmallSat) mission requirements and indicate a total MEP 650 engine efficiency of 35.5%, thrust of 30 mN, and specific impulse of 1,581 seconds at a discharge power of 650 W in self-heating mode. The MEP 650 system has completed all testing identified to achieve a Technology Readiness Level (TRL) 6.

Background

Applications:

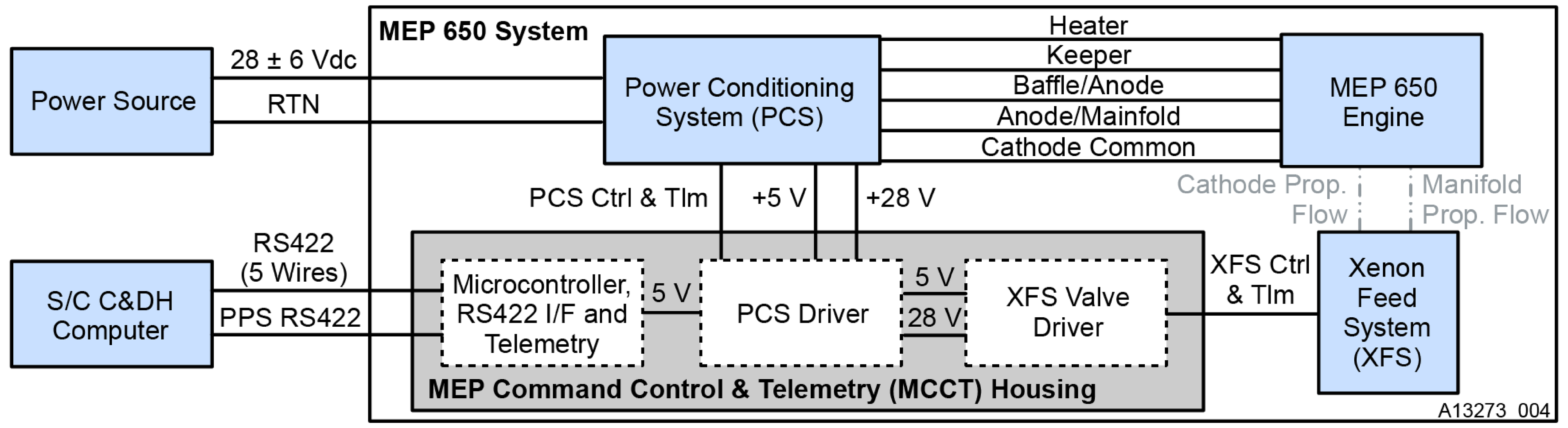
The use of electric propulsion (EP) for multiple mission profiles such as station keeping, spiral orbit maneuvers, orbit repositioning, interplanetary transfers, drag compensation and constellation phasing has grown steadily. These opportunities have encouraged the space community to explore novel EP solutions while continuing to improve on well-established technologies such as Hall Effect Thrusters (HET). MEP engine technology has been in development by the Electric Propulsion Laboratory (EPL) since 1990 to address the need for a low cost, high specific impulse EP solution for both small and large satellites

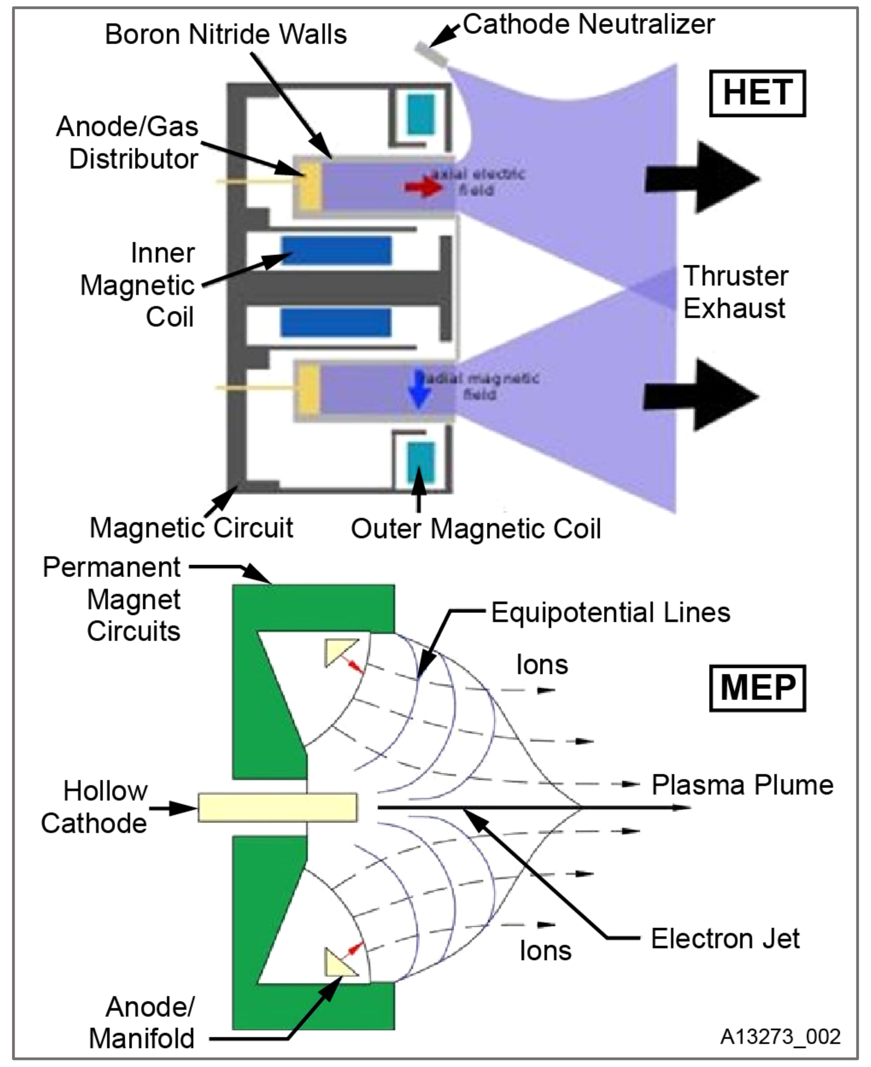
Unique Physics:

It is important to note the physics of MEP engine operation and fundamental differences between MEP engine technology and traditional HETs. Unlike HETs, which use a narrow, annular discharge chamber operating at relatively high plasma pressures, MEP engines have a large discharge volume which operates at relatively low pressures. No insulator channels are required in the MEP engine since the large discharge plasma volume is contained by careful design of the magnetic and electric fields. These fundamental design differences are highlighted by the schematic drawings on the right

Heritage:

As part of the United States Air Force (USAF) FalconSAT-8 spacecraft mission, EPL developed a 180 W MEP system operating on Krypton. The MEP 180 system was delivered to the USAF on October 1, 2017. The FalconSAT-8 spacecraft was launched in May of 2020. EPL's MEP 180 propulsion system has successfully fired dozens of times and as of the publication of this paper, the mission is ongoing. Figure 3 shows EPL's MEP 180 propulsion system. Many of the flight qualified components on this system are shared with the TRL 6 MEP 650 propulsion system.





Results

Qualification Process:

The process followed by EPL for qualification of the MEP 650 system was defined by the task flow schematic reproduced in the lower left. Hardware and system operations were performed by the Command Control and Telemetry unit shown in the schematic at the right. This computer control interface was principally used towards the end of the qualification process in support of full system level end-to-end testing under vacuum. Component level testing to TRL 6 of the Power Conditioning System (PCS), Engine and Xenon Feed System (XFS) was performed over a period of multiple months both in air, in vacuum, and under precisely control TVAC conditions.

End-to-end system level testing was first performed in EPL's very large BAT facility with only partial test completion due to facility contamination from an earlier program which resulted in excessively high background pressures. Final system level testing was performed completely and successfully in EPL's large Tank M facility which maintained background pressures in the mid 10-6 Torr range during operation of the MEP 650 engine.

Outcome:

All development tasks are completed and verified, including an endurance test that confirmed 947 hours at a discharge power of 684 W (equivalent to 997 hours at 650 W) which was identified as key to demonstrating TRL 6 status. An integrated in-vacuum "end-to-end" system level test was also successfully completed. The MEP engine exceeded development activity performance goals: total engine efficiency up to 35.5%, thrust of 30 mN and specific impulse of 1,581 seconds while operating at a discharge power of 650 W.

Before the MEP system is integrated to a Ball SmallSat, a series of activities will be performed by EPL to demonstrate integration readiness.