

MEMS Reaction Control and Maneuvering for Picosat Beyond LEO

The MEMS Reaction Control and Maneuvering for Picosat Beyond LEO project will further develop a multi-functional small satellite technology for low-power attitude control, or orientation, of picosatellites beyond low Earth orbit (LEO). The Film-Evaporation MEMS Tunable Array (FEMTA) concept initially developed in 2013, is a thermal valving system which utilizes capillary forces in a microchannel to offset internal pressures in a bulk fluid. The local vapor pressure is increased by resistive film heating until it exceeds meniscus strength in a nozzle which induces vacuum boiling and provides a stagnation pressure equal to vapor pressure at that point which is used for propulsion. Interplanetary CubeSats can utilize FEMTA for high slew rate attitude corrections in addition to desaturating reaction wheels. The FEMTA in cooling mode can be used for thermal control during high-power communication events, which are likely to accompany the attitude correction. Current small satellite propulsion options are limited to orbit correction whereas picosatellites are lacking attitude control thrusters. The available attitude control systems are either quickly saturated reaction wheels or movable high drag surfaces with long response times.

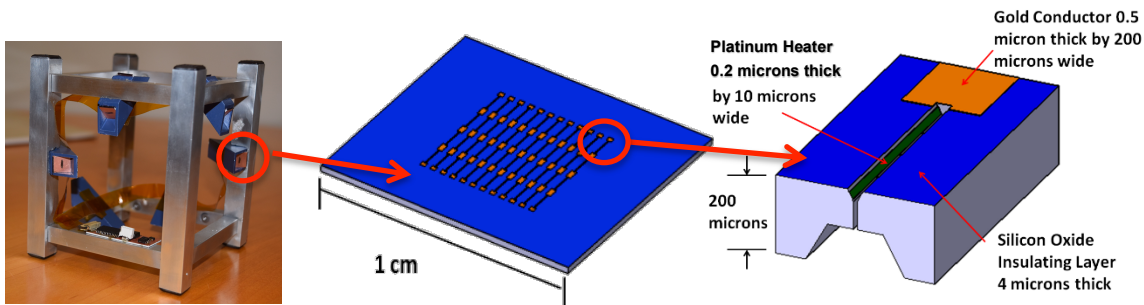
The valveless design of the FEMTA allows the propellant storage to be integrated with the nozzle itself reducing mass and complexity and the propellant of choice, water, requires no special handling as it is the definition of green. The nozzle and thermal valve system mass are less than 0.1 gram such that propellant could

compose as much as 80% of a 2-gram device.

Three generations of thrusters have been fabricated and tested: the first provided proof of concept, the second provided idle mode evaporation rate data, and the third quantified thrust performance. Thrust to power has been measured at approximately 230 $\mu\text{N/W}$ with thruster efficiency (specific impulse [I_{sp}]), of about 90 seconds for nozzles with throat length to width ratio of around 4. The next generation of devices will focus on developing a shutter system to reduce off-time evaporative losses and extend mission lifetimes. This may be either electrostatically or electrothermally actuated and should not substantially increase power consumption. An integrated Resistance Temperature Detector (RTD) will be added to monitor meniscus temperature during firing to provide empirical data for comparison with numerical models so that performance of future generations might be made mission specific. Minimum repeatable impulse bit will be determined so that a metric for pointing accuracy can be obtained.

Conventional attitude control for pico- and nano- class satellites in LEO is currently performed by a combination of reaction wheels with magnetorquers for periodic desaturation. Outside the planetary magnetic field such as with a lunar mission or probe in deep space, this combination would be rendered inoperable. Microthrusters are the only option for high precision pointing. A precision 3-axis attitude control system for a 1-unit (1U) CubeSat would

NASAfacts



2D slot type Film Evaporation Mems Tunable Array (FEMTA): (a) Model of 12 FEMTAs for 3-axis control on a CubeSat; (b) 4x12 FEMTA array; (c) close-up of a single element of FEMTA inlet side up showing 60 to 10 micron converging inlet and electrical connectors.

be composed of 12 FEMTA thrusters that would be tunable to remove jitter associated with other systems that are unable to compensate for uneven mass distribution. The propellant mass fraction of these is typically low due to the non-scalability of valving and power components. FEMTA can fill this requirement as it is compact and requires less than 1 watt of power. With this type of attitude control, picosatellites can play a more diverse role outside LEO such as telemetry relays for orbit insertion or for grounded vehicles. Single picosatellite surveyors could detect mineral compositions of individual asteroids as a precursor to mining. Picosatellite constellations could enable single pass contour mapping of extraterrestrial surfaces or precise positioning of primary spacecraft.

This project directly supports the need for new small satellite technologies in the areas of propulsion and thermal management. The FEMTA subsystem enables picosatellite capabilities for orbital maneuvering, formation flying, proximity operations, rendezvous, docking and precision pointing.

Collaborators on this project include the School of Aeronautics and Astronautics and Birck Nanotechnology Center at Purdue University in West Lafayette, Indiana and NASA's Goddard Space Flight Center in Greenbelt, Maryland.

This project is funded through the SmallSat Technology Partnerships, a program within the Small Spacecraft Technology Program (SSTP). The SSTP is chartered to develop and mature technologies to enhance and expand the capabilities of small spacecraft with a particular focus on communications, propulsion, pointing, power, and autonomous operations. The SSTP is one of nine programs within NASA's Space Technology Mission Directorate.

For more information about the SSTP, visit:
<http://www.nasa.gov/smallsats>

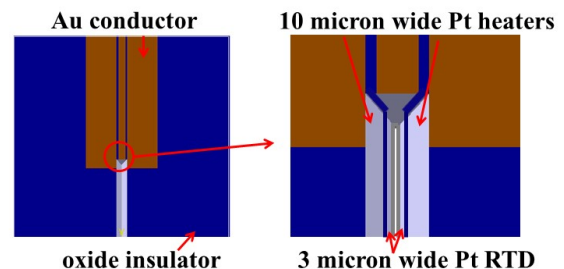
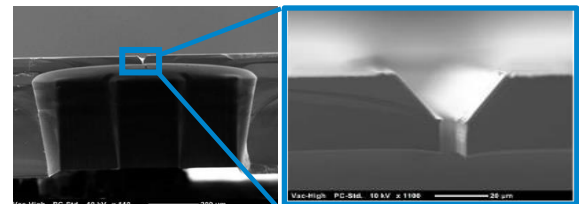
For more information about this project, please contact:

Alina Alexeenko
 Associate Professor
 School of Aeronautics and Astronautics
 Purdue University
 Alexeenk@purdue.edu

Eric Cardiff
 Propulsion Engineer
 Goddard Space Flight Center
 Eric.H.Cardiff@nasa.gov

Roger C. Hunter
 Small Spacecraft Technology Program Manager
 Space Technology Mission Directorate
 NASA Ames Research Center
 Roger.C.Hunter@nasa.gov

Andrew Petro
 Small Spacecraft Technology Program Executive
 Space Technology Mission Directorate
 NASA Headquarters
 Andrew.J.Petro@nasa.gov



SEM photo of third generation FEMTA nozzle cross section (top left); close-up of nozzle inlet and throat (top right); schematic of proposed integrated RTD (bottom left); close-up (bottom right).

National Aeronautics and Space Administration

Ames Research Center
 Moffett Field, CA 94035

www.nasa.gov