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 μN/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

![Diagram of FEMTA](https://ntrs.nasa.gov/search.jsp?R=20160007910)
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).