I have been investigating the use of miniaturized electrodynamic tethers (EDTs) to enhance the capabilities of femtosatellites and other ultra-small satellites. The emerging success of and interest in nanospacecraft (1–10 kg) has generated interest in exploring the potential for even smaller spacecraft, both as stand-alone satellites or as a distributed swarm. Effectively, this architecture can be thought of as a small “satellite-on-a-chip,” or ChipSat. ChipSats belong to the picosatellite (100 g–1 kg) and femtosatellite (<100 g) mass categories. However, flat ChipSat wafers can have an inherently high area-to-mass ratio, which results in an undesirably short orbital life in low Earth orbit (LEO) due to atmospheric drag, ranging from a few weeks to a few hours.

The use of a very short (few meters), semi-rigid electrodynamic tether for femtosatellite propulsion has been investigated. I analyzed the EDT anode’s ability to draw current from the ionosphere and thereby generate thrust and have traded this performance against the tether mass and material, electron emitter and collector types, and power needed to determine the EDT’s capability of overcoming atmospheric drag forces. The study led to the development of a system concept and mission scenario using the simulation tool TeMPEST to estimate tether voltages and currents based on tether configuration and ambient models. The results reveal that an insulated tether, only a few meters long and tens of microns in diameter, can provide milligram to gram-level ChipSats with complete drag cancellation and even the ability to change orbit. Further, a few meter tether could also serve as a communications or a scientific radio antenna, serves as a plasma diagnostics probe, and even a boom for passive attitude stability along the local vertical.

The next step is to build on existing trade studies and demonstrate, through simulation and a proposed experiment, that the EDT system is capable of collecting sufficient current and generating the Lorentz force required for propulsion. I am currently preparing to conduct a ground-based plasma chamber experiment in which the key plasma parameters scale with ionospheric plasmas. We will also investigate how the EDT system can be used as a Langmuir probe.

The results have been presented at the Michigan Institute of Plasma Science and Engineering (MIPSE) research symposium in Ann Arbor, Michigan; the International Electric Propulsion Conference (IEPC) in Weisbaden, Germany; the Space Charging Technology Conference (SCTC) in Kitakyushu, Japan; the International Conference on Plasma Science (ICOPS) in Edinburgh, Scotland; the American Institute of Aeronautics and Astronautics (AIAA) Space 2011 conference in Long Beach, California; the Great Midwestern Space Grant Regional Meeting in Champaign, Illinois; and the Joint Army Navy NASA Air Force (JANNAF) Propulsion Meeting in Huntsville, Alabama.