



## Mechanics/Machinery

### UltraSail CubeSat Solar Sail Flight Experiment

**Solar sail will feature new approaches that will result in larger sail areas and larger payloads.**

*Marshall Space Flight Center, Alabama*

UltraSail is a next-generation, high-risk, high-payoff sail system for the launch, deployment, stabilization, and control of very large (km<sup>2</sup> class) solar sails enabling high payload mass fractions for interplanetary and deep space spacecraft. UltraSail is a non-traditional approach to propulsion technology achieved by combining propulsion and control systems developed for formation-flying microsatellites with an innovative solar sail architecture to achieve controllable sail areas approaching 1 km<sup>2</sup>, sail subsystem area densities approaching 1 g/m<sup>2</sup>, and thrust levels many times those of ion thrusters used for comparable deep space missions. UltraSail can achieve outer planetary rendezvous, a deep-space capability now reserved for high-mass nuclear and chemical systems.

There is a twofold rationale behind the UltraSail concept for advanced solar sail systems. The first is that sail-and-boom systems are inherently size-limited. The boom mass must be kept small, and column buckling limits the boom length to a few hundred meters. By eliminating the boom, UltraSail not only offers larger sail area, but also lower areal density, allowing larger payloads and

shorter mission transit times. The second rationale for UltraSail is that sail films present deployment handling difficulties as the film thickness approaches one micrometer. The square sail requires that the film be folded in two directions for launch, and similarly unfolded for deployment.

The film is stressed at the intersection of two folds, and this stress varies inversely with the film thickness. This stress can cause the film to yield, forming a permanent crease, or worse, to perforate. By rolling the film as UltraSail does, creases are prevented. Because the film is so thin, the roll thickness is small. Dynamic structural analysis of UltraSail coupled with dynamic control analysis shows that the system can be designed to eliminate longitudinal torsional waves created while controlling the pitch of the blades, while using solar photon pressure to slew the spin axis. Vacuum tests have also verified that electrostatic and molecular adhesion forces can substantially be eliminated by making the film electrically conductive, reducing the peel force of the film off the storage roll to levels of 100s of micro-N.

The innovation demonstrated the capability of deploying a six-micron alu-

minum-coated film from a reel through a slit in vacuum. The innovation also demonstrated a spin-stabilized method for deploying a long reel of solar sail film using solar pressure to spin-up and orbit raise the satellite, and also a gravity gradient method for deploying a long reel of solar sail film using solar pressure to orbit raise the satellite.

The solar sail mass fraction of 25% is consistent with high specific impulse ion systems, but without the added weight and cost of a power source and processing unit. The large sail area, coupled with low film density, is giving UltraSail a high payload fraction. The UltraSail deployment scheme unrolls a micrometer-scale reflection-coated polyimide film from a storage mandrel to a maximum length of several kilometers with the aid of a blade tip satellite.

*This work was done by David Carroll and Rodney Burton of CU Aerospace L.L.C., Victoria Coverstone of the University of Illinois at Urbana-Champaign, and Gary Swenson of the University of Illinois for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at [sammy.a.nabors@nasa.gov](mailto:sammy.a.nabors@nasa.gov). Refer to MFS-32949-1.*

### Mechanism for Deploying a Long, Thin-Film Antenna From a Rover

**The deployment mechanism consists of two rollers to automatically deploy the antenna at a rate proportional to the wheel speed.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Observations with radio telescopes address key problems in cosmology, astrophysics, heliophysics, and planetary science including the first light in the Universe (Cosmic Dawn), magnetic fields of extrasolar planets, particle acceleration mechanisms, and the lunar ionosphere. The Moon is a unique science platform because it allows access to radio frequencies that do not penetrate the Earth's ionosphere and because its far side is shielded from intense terrestrial emissions. A

radio antenna can be realized by using polyimide film as a substrate, with a conducting substance deposited on it. Such an antenna can be rolled into a small volume for transport, then deployed by unrolling, and a robotic rover offers a natural means of unrolling a polyimide film-based antenna. An antenna deployment mechanism was developed that allows a thin film to be deposited onto a ground surface, in a controlled manner, using a minimally actuated rover.

The deployment mechanism consists of two rollers, one driven and one passive. The antenna film is wrapped around the driven roller. The passive roller is mounted on linear bearings that allow it to move radially with respect to the driven roller. Springs preload the passive roller against the driven roller, and prevent the tightly wrapped film from unspooling or "bird's nesting" on the driven spool. The antenna deployment mechanism is integrated on the