Mechanics/Machinery

Ultra-Large Solar Sail

Marshall Space Flight Center, Alabama

UltraSail is a next-generation ultra-large (km^2 class) sail system. Analysis of the launch, deployment, stabilization, and control of these sails shows that high-payload-mass fractions for interplanetary and deep-space missions are possible. UltraSail combines propulsion and control systems developed for formation-flying microsatellites with a solar sail architecture to achieve controllable sail areas approaching 1 km^2. Electrically conductive CP-1 polyimide film results in sail subsystem area densities as low as 5 g/m^2. UltraSail produces thrust levels many times those of ion thrusters used for comparable deep-space missions.

The primary innovation involves the near-elimination of sail-supporting structures by attaching each blade tip to a formation-flying microsatellite, which deploys the sail and then articulates the sail to provide attitude control, including spin stabilization and precession of the spin axis. These microsatellite tips are controlled by microthrusters for sail-film deployment and mission operations.

UltraSail also avoids the problems inherent in folded sail film, namely stressing, yielding, or perforating, by storing the film in a roll for launch and deployment. A 5-km long by 2 micrometer thick film roll on a mandrel with a 1 m circumference (32 cm diameter) has a stored thickness of 5 cm. A 5 m-long mandrel can store a film area of 25,000 m^2, and a four-blade system has an area of 0.1 km^2.

This work was done by Rodney Burton and Victoria Coverstone of the University of Illinois Urbana-Champaign for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32524-1

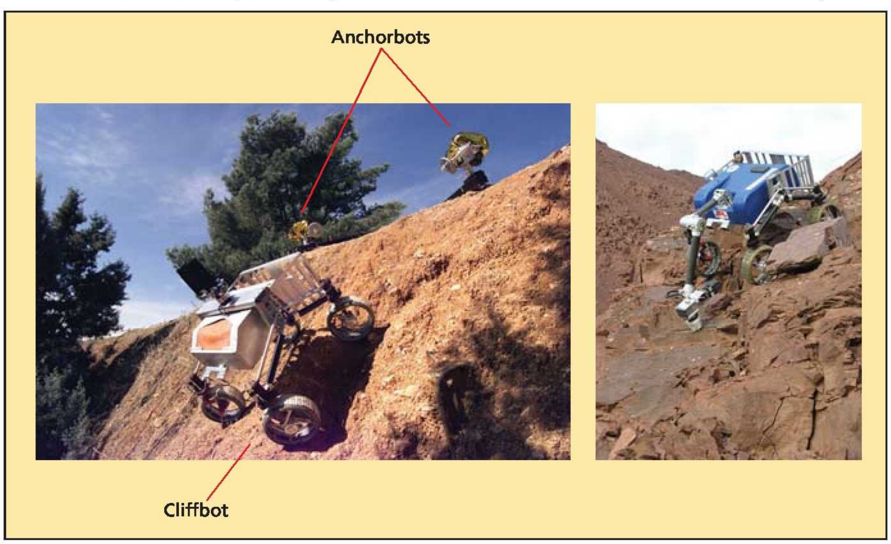
Cooperative Three-Robot System for Traversing Steep Slopes

This system is modeled on safe human climbing of steep slopes.

NASA's Jet Propulsion Laboratory, Pasadena, California

Teamed Robots for Exploration and Science in Steep Areas (TRESSA) is a system of three autonomous mobile robots that cooperate with each other to enable scientific exploration of steep terrain (slope angles up to 90°). Originally intended for use in exploring steep slopes on Mars that are not accessible to lone wheeled robots (Mars Exploration Rovers), TRESSA and systems like TRESSA could also be used on Earth for performing rescues on steep slopes and for exploring steep slopes that are too remote or too dangerous to be explored by humans.

TRESSA is modeled on safe human climbing of steep slopes, two key features of which are teamwork and safety tethers. Two of the autonomous robots, denoted Anchorbots, remain at the top of a slope; the third robot, denoted the Cliffbot, traverses the slope. The Cliffbot drives over the cliff edge supported by tethers, which are payed out from the Anchorbots (see figure). The Anchorbots autonomously control the tension in the tethers to counter the gravitational force on the Cliffbot. The tethers are payed out and reeled in as needed, keeping the body of the Cliffbot oriented approximately parallel to the local terrain surface and preventing wheel slip by controlling the speed of descent or ascent, thereby enabling the Cliffbot to drive freely up, down, or across the slope.



Left: The **Cliffbot Is Tethered to the Two Anchorbots** so that it can move on the steep slope. Right: The Cliffbot performs scientific studies of the cliff.

Due to the interactive nature of the three-robot system, the robots must be very tightly coupled. To provide for this tight coupling, the TRESSA software architecture is built on a combination of (1) the multi-robot layered behavior-coordination architecture reported in "An Architecture for Controlling Multiple Robots" (NPO-30345), *NASA Tech Briefs*, Vol. 28, No. 10 (October 2004), page 65, and (2) the real-time control architecture reported in "Robot Electronics Architecture" (NPO-41784), *NASA Tech*