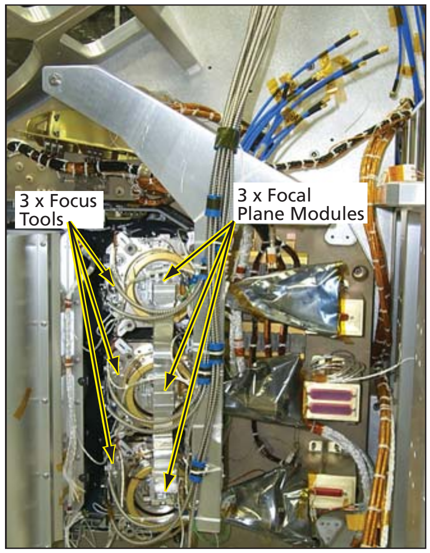
assembly, and three optical-displacement metrology sensors that can be read from outside the thermal vacuum chamber. The motors are used to drive the focal planes to different focal distances and acquire images, from which it is possible to determine the best focus. At the best focus position, the three optical displacement metrology sensors are used to determine the shim thickness needed. After the instrument leaves the thermal vacuum chamber, the focus tool is replaced with the precision-ground shim ring.

The focus tool consists of two sets of collars, one that mounts to the backside of the interface flange of the instrument optics, and one that mounts to the backside of the interface flange of the focal plane modules. The collars on the instrument optics side have the three small piezo-actuated motors and the three optical displacement metrology systems. Before the instrument is focused, there is no shim ring in place and, therefore, no fasteners holding the focal plane modules to the cameras. Two focus tooling collars are held together by three strong springs.



The three **Focal-Plane Modules and the Focus Tools** are shown on the OCO flight instrument, where space was very tight. The image was taken before thermal blanketing was installed.

The Orbiting Carbon Observatory (OCO) mission spectrometer was focused this way (see figure). The motor described here had to be moved five times to reach an acceptable focus, all during the same thermal cycle, which was verified using pupil slicing techniques. A focus accuracy of ≈20–100 microns was achieved.

This work was done by Carl Christian Liebe, Brett Hannah, Randall Bartman, Costin Radulescu, Mayer Rud, Edwin Sarkissian, and Timothy Ho of Caltech; Randy Pollock, Joseph Esposito, Brian Sutin, and Robert Haring of Hamilton Sundstrand Corp.; and Juan Gonzalez (contractor) for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov. NPO-45749

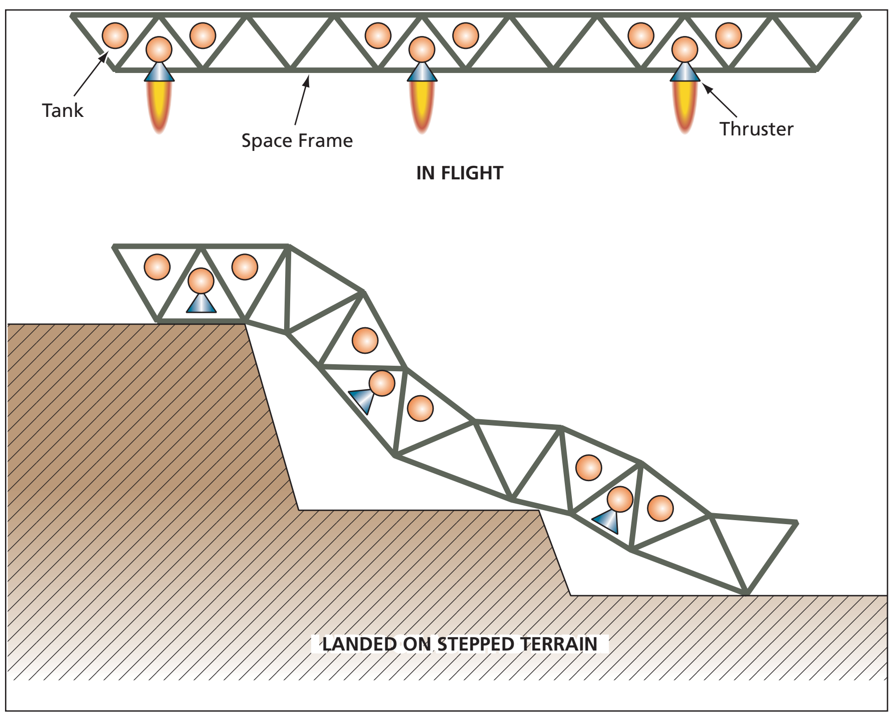
Space-Frame Lunar Lander

This structure would deform itself to sit stably on rough terrain.

Goddard Space Flight Center, Greenbelt, Maryland

The space-frame lunar lander is a conceptual spacecraft or spacecraftlike system based largely on the same principles as those of the amorphous rover and the space-frame antenna described in the two immediately preceding articles. The space-frame lunar lander was originally intended to (1) land on rough lunar terrain, (2) deform itself to conform to the terrain so as to be able to remain there in a stable position and orientation, and (3) if required, further deform itself to perform various functions. In principle, the space-frame lunar lander could be used in the same way on Earth, as might be required, for example, to place meteorological sensors or a radio-communication relay station on an otherwise inaccessible mountain peak.

Like the amorphous rover and the space-frame antenna, the space-frame lunar lander would include a trusslike structure consisting mostly of a tetrahedral mesh of nodes connected by variable-length struts, the lengths of which would be altered in coordination to impart the desired overall size and shape to the structure. Thrusters (that is, small rocket engines), propellant tanks, a control system, and instrumentation would be mounted in and on the structure (see figure). Once it had landed and deformed itself to the terrain through coordinated variations in the lengths of the struts, the structure could be further deformed into another space-frame structure (e.g., the amorphous rover or the space-frame antenna).



A **Spacecraftlike System** looking like a truss equipped with thrusters would land on and conform to an irregular terrain surface.

Also like the amorphous rover and the space-frame antenna, the space-frame lunar lander could be designed and built using currently available macroscopic electromechanical components or by exploiting microelectromechanical systems (MEMS), nanoelectromechanical systems (NEMS), or carbon nanotubes, and any or all of these versions could include control systems based partly on evolvable neural software systems. The areal mass densities of these versions are expected to be comparable to those of the corresponding versions of the space-frame antenna.

This work was done by Steven A. Curtis of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-14848-1