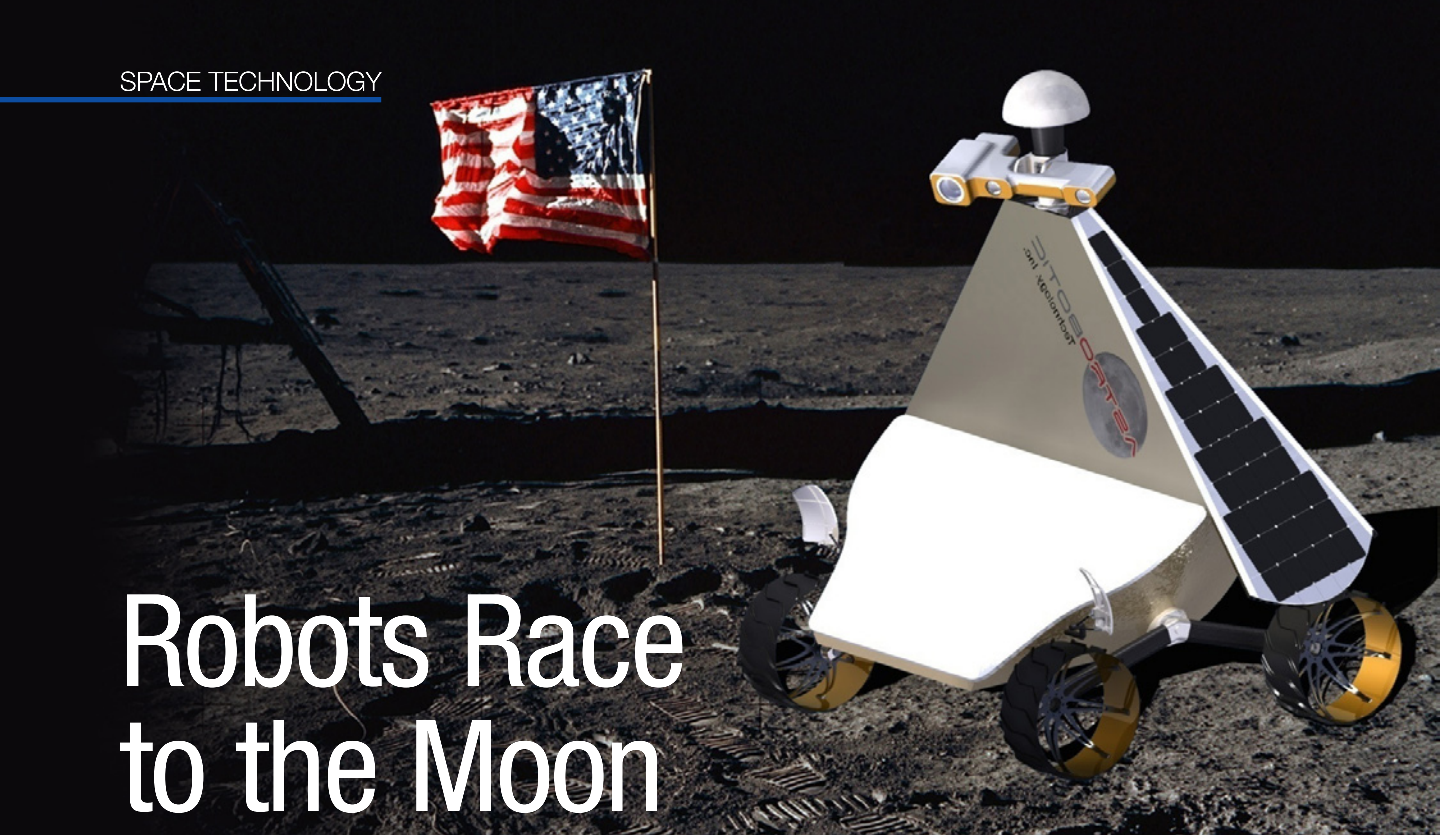


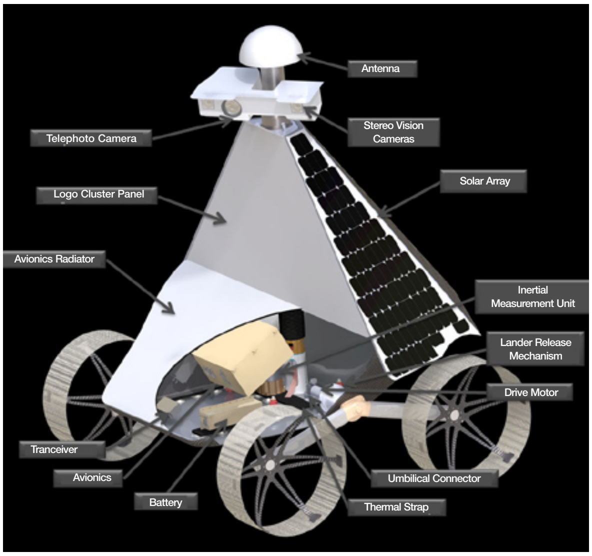
Robots Race to the Moon

Engineering simulation plays key role in developing a robot for a $20 million international lunar competition.

Artist's compilation shows the robot moving across the lunar surface from the landing module.

By David Gump, President, Astrobotic Technology Inc., Pittsburgh, U.S.A.

The first privately funded team to send a robot to the moon, travel 500 meters, and transmit HD-quality video images back to Earth will win the Google Lunar X PRIZE competition. The winner will be awarded $20 million, with $5 million for second place and $5 million for bonus events. The project will pave the way for more extensive human exploration of the moon, evaluation of potential sites for interplanetary-mission base stations, and investigation of lunar natural resources.



The Astrobotic lunar robot has numerous critical components and subsystems that must operate effectively in the harsh lunar environment.

One of the 21 teams from around the world participating in the competition is U.S.-based Astrobotic Technology Inc., a spin-off of the Robotics Institute at Carnegie Mellon University. The university is serving as the design-and-test site for initial concept prototypes of a lunar rover robot for the company's Tranquility Trek™ mission to the moon on a rocket such as Falcon 9 from Space Exploration Technology (SpaceX).

After launch and capture into a lunar orbit, a landing module will descend and be slowed by a set of retro-rockets to make a controlled soft landing. The module then will release the robot to move down a ramp onto the lunar surface to begin its mission. Powered by a 120-Watt solar array with an auxiliary battery, the 1.5-meter-high robot will move at 5 centimeters to 10 centimeters per second via a chain-driven four-wheel drive system. For the Tranquility Trek mission, Astrobotic Technology intends for the robot to visit Apollo 11's landing site along the lunar equator to study the lunar environment's effects on materials that mission left behind.

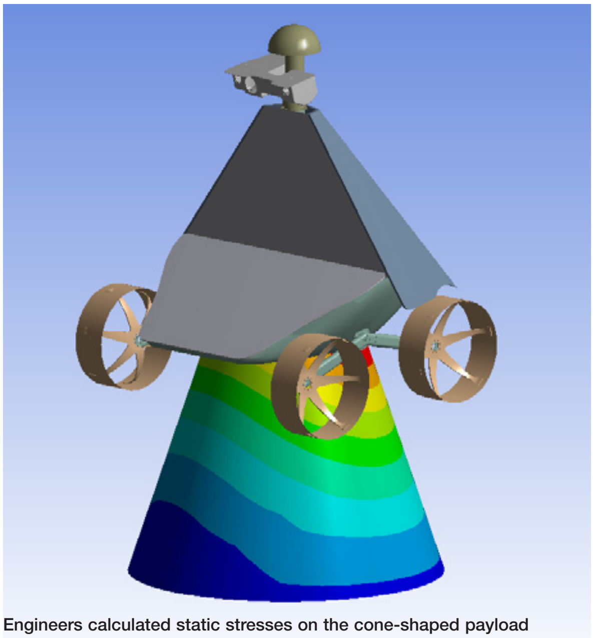
As an official sponsor of the Astrobotic lunar project, ANSYS is providing its multiphysics engineering simulation software and applications support. The technology is being used primarily in the development of the robot, the four-legged lander and a payload adapter connecting the robot to the launch vehicle.

In developing the concept design for the assemblies, extensive analysis was performed using ANSYS Mechanical software in determining stress distributions of major components and assembles in withstanding up to 13 Gs of acceleration and vibration loads encountered during launch, stage separation, orbital insertion and landing.

Engineers focused in particular on analysis of the robot's all-composite structure — a groundbreaking innovation in lunar rover design intended to combine high strength and stiffness with the ability to keep the machine cool. Simulations also studied the effectiveness of the payload adapter in withstanding these extreme loads and having sufficient structural flexibility to damp the transfer of damaging vibrations from the launch vehicle to the robot. Numerous simulations were performed in evaluating different adapter geometries and materials, including titanium and aluminum as well as various combinations of solid, sandwiched and honeycombed carbon-fiber composite materials.

In these simulations, engineers conducted parametric design optimization studies using ANSYS DesignXplorer software and the scripting capabilities of the ANSYS Parametric Design Language (APDL). Through hundreds of iterations performed automatically in just a few hours, engineers leveraged the software to find the lowest-cost, lightest-weight designs for the robot and the deep-space transfer stages that will deliver it to the moon. ANSYS simulation technology enabled the research team to examine alternative structures and materials to find the most effective combination in the early concept stages of development, before physical prototypes were built.

In these simulations, ANSYS contact elements were used in models to automatically transfer mechanical force loads across joints between mating parts, instead of performing this task manually. The same contact elements were used in transferring thermal energy loads across these boundaries in exhaustive simulations to study heat flow and temperatures in the robot structure.



Engineers calculated static stresses on the cone-shaped payload adapter from mechanical loads that would be encountered during launch, rocket stage separation and orbital insertion.

Steady-state thermal study shows temperature distribution on the radiator and surrounding panels used to dissipate excess heat generated by the robot.

These studies performed with the thermal analysis capabilities of ANSYS Mechanical software were instrumental in helping engineers to determine an optimal robot design to survive the large temperature variations and heat dissipation challenges of the lunar environment. Lunar areas lit by the sun are baked at 100 degrees C, while temperatures plummet to minus 200 degrees C in shaded areas — a drastic thermal difference ranging from the temperature of boiling water to that of liquid nitrogen. Engineers had to consider this thermal cycling because differences in thermal expansions of various components cause conventional fasteners, solder joints, snap fits other parts to pop, fracture, and otherwise degrade.

Compounding the difficulties, the almost nonexistent atmosphere on the moon means that there is no convection cooling. Fans, therefore, are absolutely ineffective in removing thermal energy from internal electronic and electrical components for control circuitry, motors and actuators. Moreover, lunar regolith — the powdery dust covering the surface of the moon — is highly insulative, reflecting radiant energy from the sun and any internally generated heat back onto the robot.

Engineers solved the problem of removing waste heat from the robot by installing a large white panel on the robot's side that will always face away from the sun, which will radiate excess heat to black space. Numerous simulations were performed to find the optimal surface area and orientation of the radiator as well as to study sunlight hitting the robot at different angles — to explore the effectiveness of the various asymmetrical shapes of the robot outer shell and to evaluate the thermal conductivities of the composite structure of the robot.

ANSYS multiphysics simulation was instrumental in evaluating hundreds of these complex mechanical and thermal loading scenarios. Performing these studies using software with wide-ranging advanced technology enabled the Astrobotic Technology engineering team to optimize the structure during the early concept stages of development. The technology will be used for more in-depth studies as the robot and support equipment proceed through detailed design phases. Optimizing the design of complex assemblies to operate properly under such adverse conditions would not be practical without the ability to performing exhaustive simulations so quickly. ■