National Aeronautics and Space Administration

NASA**facts**

Space Technology
Game Changing Development
PUFFER: Pop-Up Flat Folding Explorer Robots

The PUFFER project is developing a novel origami-inspired, ultra-compact rover technology to expand the scientific reach of future NASA missions. PUFFER is a "pop-up" robot that folds into a small, smartphone-sized weight and volume. This compactness allows a large number of PUFFERs to be packed into a larger "parent" spacecraft at low payload cost, and then used by the parent spacecraft to provide increased surface mobility. Example missions could include a planetary lander that requires small rovers for increased exploration. Alternatively, a larger parent rover could use a collection of PUFFERs to explore extreme terrains that are easier to access with a small, low-cost "child" rover. When the parent spacecraft finds an exciting region for exploration, it simply ejects one or more PUFFERs, which then pop-up and go on to explore the target of interest.

The PUFFER project is an 18-month effort led by JPL in collaboration with academic and industry partners at the University of California, Berkeley and at Distant Focus Corporation in Champaign, Illinois. The effort will produce a set of instrumented prototypes that will be demonstrated through Mars-analog field tests in early 2017.

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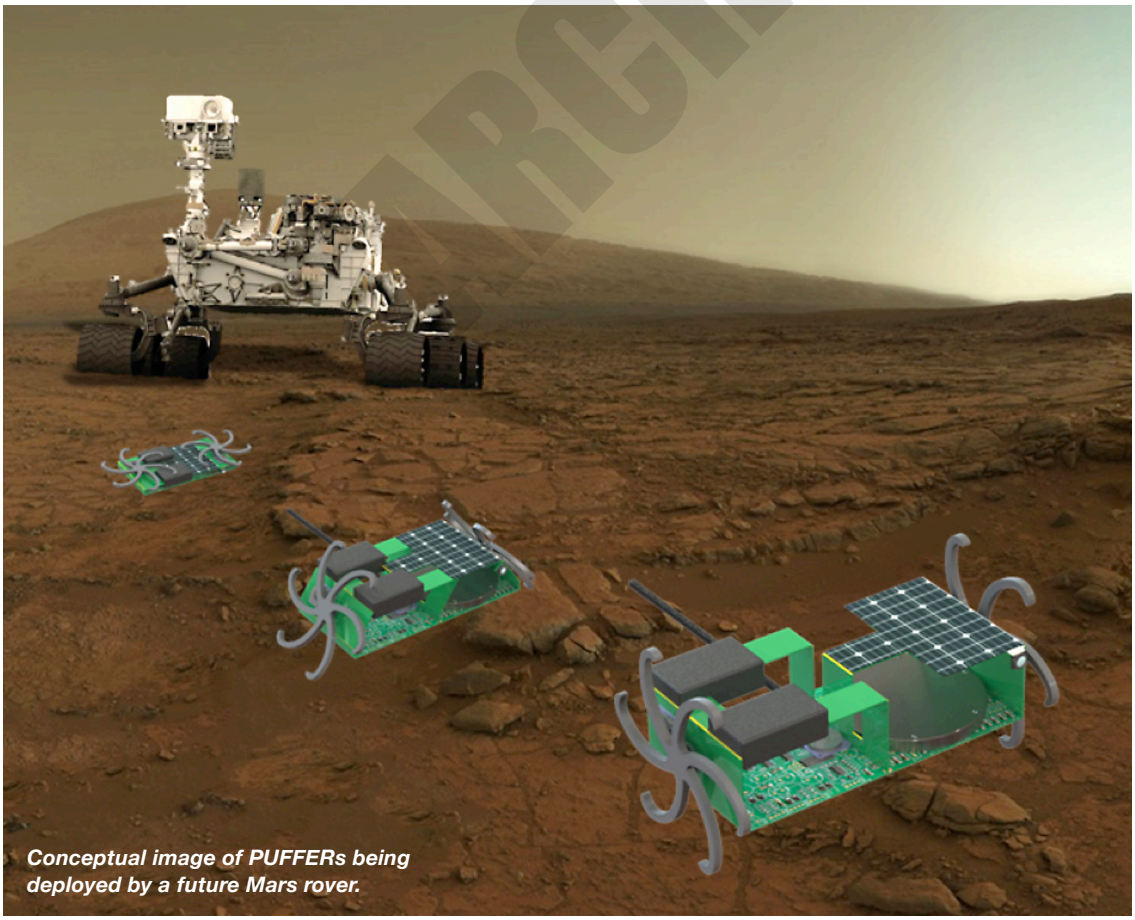
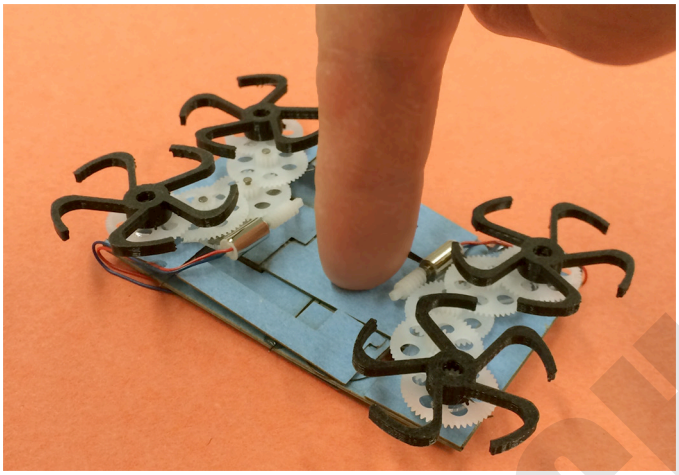
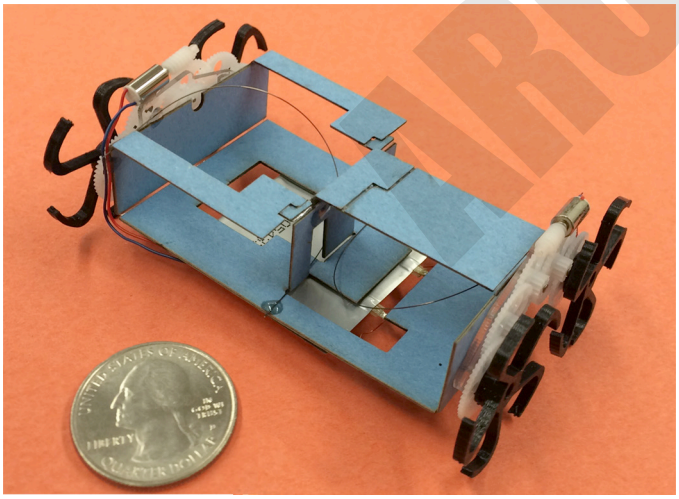


Conceptual image of PUFFERs being deployed by a future Mars rover.

The JPL PUFFER team is collaborating with The U.C. Berkeley Biomimetic Millisystems Lab to develop novel origami-inspired pop-up structures. These structures will be able to house PUFFER's components and instruments as well as fold into a convenient volume for compact storage. The researchers at U.C. Berkeley are drawing on over a decade of expertise in origami-robot design to satisfy the unique requirements of the PUFFER pop-up structure. JPL is leveraging its experience to transition these new pop-up structure designs to robust materials and constructions that are compatible with the rigors of space flight. Early prototypes have investigated using folding printed circuit boards to integrate the robot's electronics directly into the folding structure.





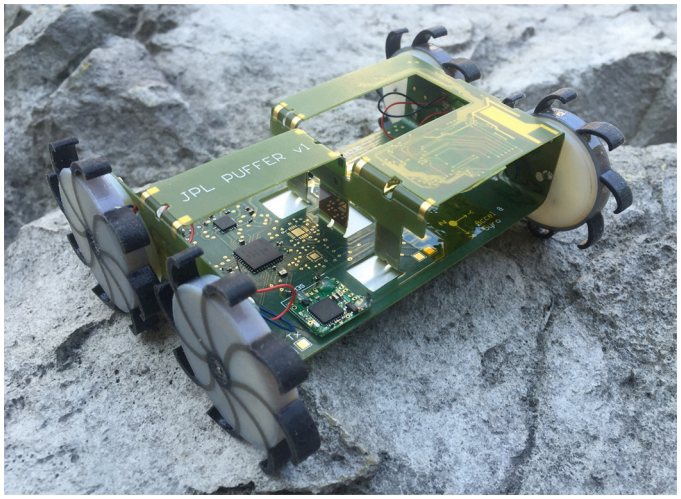
Early PUFFER prototype, shown folded flat (above) and fully deployed (below). Total mass is 12 grams.

The JPL team's partnership with Distant Focus Corporation will develop a unique folded optic microscope for use on the PUFFER rovers. A folded optic microscope uses a series of reflective mirrors, as opposed to refractive lenses, that allows the instrument to be packed into a very thin profile. The thin profile then enables the microscope to be readily integrated into PUFFER's flat folding structure. Distant Focus Corporation will design and fabricate a batch of folded optic microscopes and deliver these to JPL for integration and field testing at the end of the PUFFER development effort.

At the end of the current project, the PUFFER team will demonstrate PUFFER's use in a number of exciting Mars science applications through field tests in California's Mojave Desert. The PUFFER team is also exploring applications in Earth science, future exploration of Europa, and small body missions.

The Game Changing Development (GCD) Program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.

For more information about GCD, please visit http://gameon.nasa.gov/



PUFFER prototype incorporating a folding printed circuit board as its pop-up structure.

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