Senior Design Project: Miniature Actuator for Throwable Robot

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Each year, APL sponsors a project for the Whiting School of Engineering Department of Mechanical Engineering capstone course, Senior Design Project. As a part of this course, a group of undergraduate seniors works with APL staff to design and develop a system specified by APL. The students benefit from frequent personal interactions with APL staff, and APL benefits from the students' ability to deliver results (often in the form of a prototype) with a relatively small investment from APL.

Since 2003, APL has supported six projects. The annual APL call for proposals for senior design projects is issued every summer, and before the start of the academic year, a representative of the APL Chief Technology Officer and the course instructors select a project from the proposals submitted.

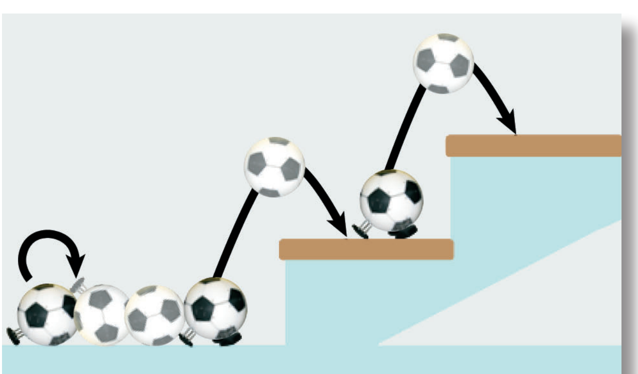

Figure 1. Stairs present a challenge for throwable robots.

In the past, projects have included development of the following:

- A variable ribbon fin propulsor for unmanned undersea vehicles
- A lighter-than-air vehicle for evaluating airborne sensors (a follow-on project developed a mechanism for tagging objects from the airborne vehicle)
- A robotic platform for off-route mine detection
- A fail-safe release mechanism to allow a series of microsatellites to be released from one main satellite at various places along an orbital path
- A door that can be opened and closed numerous times on an orbiting satellite to allow use of a delicate sensor when needed but also protect this sensor from direct exposure to the Sun when necessary
- A flexible towed retrievable antenna for use by submarines while submerged

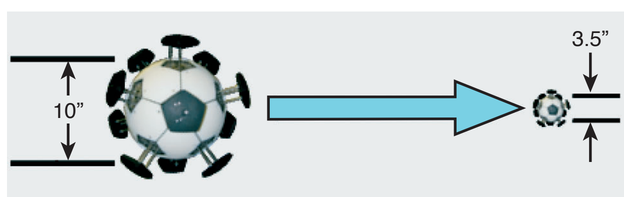

Figure 2. Envisioned size reduction of the robot with use of the student-developed actuator.

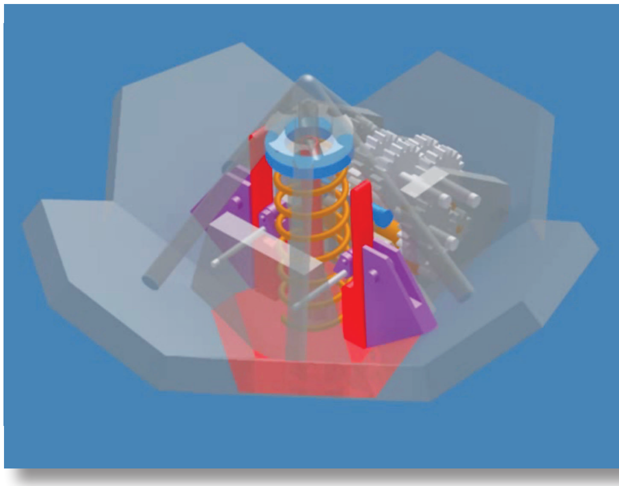

Figure 3. CAD model of the final actuator design.

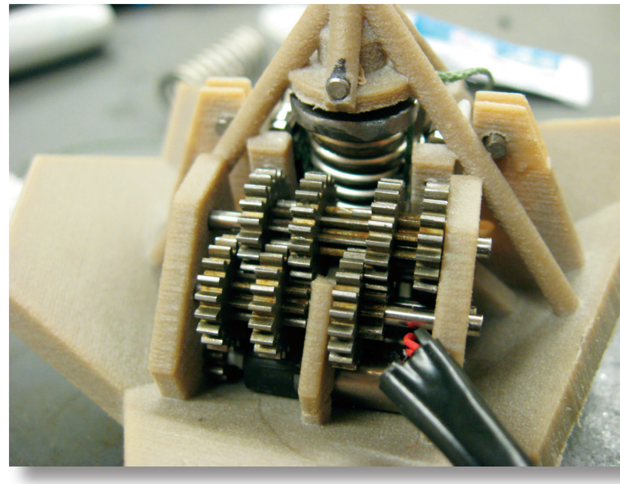

Figure 4. Final high-impulse actuator prototype.

- A long rigid boom for satellites, which is fully stowed within the spacecraft at launch but then is deployed and made rigid after the launch is completed, on command from Earth

The most recent project was the development of a compact linear actuator that would propel a small robot over obstacles such as up a flight of stairs by using energy stored in a spring. The work was done during the 2008–2009 school year and produced a functional prototype actuator. The actuator was designed to fit within the space constraints of a 3.5-inch-diameter robot, which is significantly smaller than the current 10-inch operational prototype. The final design devised by the students involved a compact DC motor used to charge an extension spring that, when released, would deliver sufficient energy to allow the robot to jump. The required energy as a function of actuator mass is as follows:

$$E = \frac{2}{\cos(40°)}(M + 0.03)g$$

E = energy (J)

M = mass (kg)

g = gravitational acceleration (m/s^2)

The challenges faced in implementing this small, high-impulse design included the design and implementation of a compact gear train, the design and fabrication of small gears (<0.25–0.5 inch in diameter), the specification and evaluation of a precision springs, and the specification and evaluation of compact COTS DC motors. Future work will focus on improving the gear train efficiency and incorporating more reliable motors before incorporating the actuators into the full mobile platform to validate APL's current simulation efforts.

For further information on the work reported here, contact mehran.armand@jhuapl.edu.