Using Rotor Technology to Land a Spacecraft

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Two of the key challenges associated with a parachute-based landing system are poor landing accuracy and excessive touchdown velocity. Poor landing accuracy forced other parachute-based vehicles to land in remote, deserted areas (Soyuz) or in the ocean (Apollo). High touchdown velocity forced some vehicles to generate crew load attenuating solutions: stroking seats (Orion); water landing (Orion and Apollo); crushable landing struts (X-38); or retro-rockets (Soyuz). Other significant constraints exist for vehicles that land as a fixed wing glider (space shuttle). These challenges laid the groundwork for the development of a radically different landing technology called Spacecraft Morphing to Auto Rotation Targeted Landing (SMART/L).

After contributing thousands of volunteer hours over a 10-year period, the SMART/L project team received its first formal funding in Fiscal Year 2011. The original concept from 2001 proposed stowing rotor blades in a basic Apollo-shaped capsule. This concept continues to head toward a tangible reality as the Johnson Space Center (JSC) team conducted the first scaled drop test in March 2011 in Building 49. The SMART/L design team envisions developing a suite of rotor-based deceleration systems for space vehicles, thus providing a viable trade alternative to parachutes.

A reentry capsule outfitted with SMART/L technology would work as follows: after reaching the right speed and altitude, blades deploy from the capsule into the free stream, initiating rotation and telescoping of the blades. The blades are pitched in a manner to most efficiently use the free stream flow and maximize the rotational momentum of the system. Then, just as a helicopter would operate in an unpowered landing, the blades of the capsule are collectively pitched to convert the rotational inertia into vehicle lift for a soft, controlled landing (figure 1). Hover time can be extended by mounting small ramjet thrusters at the rotor blade tips.

The core SMART/L team from JSC's Structural Engineering Division continues to collaborate with the Flight Mechanics and Robotics divisions, Rice University, Ames Research Center, Defense Advanced Research Projects Agency, and local radio-controlled helicopter organizations. Through these collaborations, the SMART/L team realized the following key advancements this fiscal year: scaled prototype capsule construction and drop testing from JSC Building 49's 95-ft indoor tower to test rotor spin-up and flare without motor power; retrofit of a radio-controlled helicopter into the capsule shape using ducted fans to replace the tail rotor (this enhancement enables fast turnaround, higher altitude [>1000 ft] drop testing to further assess rotor spin-up and flare using auto-rotation only); and computational flow dynamics analysis to assess loads and stability during rotor system deployment.

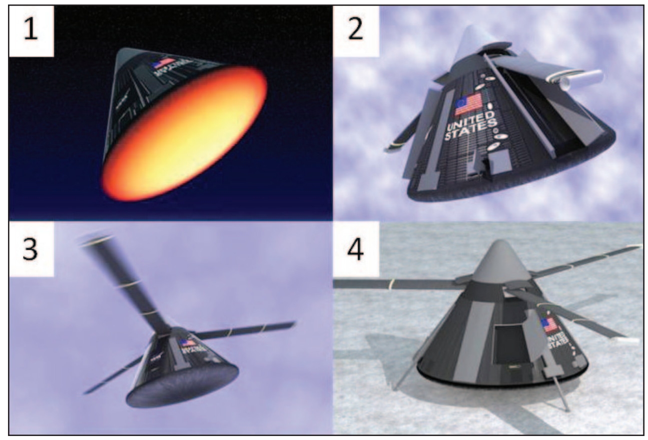

Fig. 1. *Rotor deployment sequence.*

The SMART/L team soon plans to redirect its focus toward two of the top development risks for the system: rotor blade unfolding; and rotor blade telescoping. Specifically, these focus areas will include mechanism development and ground-based testing for the deployment systems (including wind tunnel testing), enhanced deployment and stability analyses, and demonstration of controllability in auto-rotation flight leading up to integrated demonstrations of in-flight deployment and landing.

The SMART/L team believes there is vast potential for this rotor technology in the near future, whether it be to return time-critical payloads from the International Space Station directly to JSC, or to enable an injured astronaut to reenter Earth's atmosphere and land on the helipad at the Houston Medical Center.