Enabling New and Innovative Low Cost Mars Science Missions with the Adaptable, Deployable, Entry and Placement Technology (ADEPT).

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Summary: The Adaptive Deployable Entry and Placement Technology (ADEPT) offers a delivery capability for Small Sat or CubeSat orbiter(s), in-situ elements, or landers. ADEPT can deliver the same science payload to a destination with a stowed diameter a factor of 2-4 times smaller than an equivalent rigid aeroshell, alleviating volumetric constraints on the secondary payload accommodation or primary carrier spacecraft bus. The ADEPT system can support payload over a range of mass and geometries to offer a delivery capability for a single or constellation of spacecraft supporting the goals and objectives of "Low Cost Mars Science Missions."

Introduction: Development and demonstration for utilizing Small Satellites beyond low earth orbit for a wide range of planetary science missions is making steady progress. Several secondary CubeSat payload missions are under study at Mars, cis-Lunar Space, near Earth objects, Venus, and destination beyond. In some cases, these smaller systems may enable utilization of otherwise unused capacity of larger "host" missions. Development of entry systems that leverage and accommodate Small Satellite technology will substantially expand the range of mission applications by offering the capability for high-speed entry or aerocapture at destinations with atmospheres.[1] Recent development progress in Adaptive Deployable Entry and Placement Technology (ADEPT) offers unique benefits over traditional rigid aeroshells including volume, mass and payload form factor, with a delivery capability for a single or constellation of spacecraft supporting the goals and objectives of Low Cost Mars Science missions.

Technology Description for Small Spacecraft and Small EDL Missions: ADEPT is a low ballistic coefficient planetary entry system that employs an umbrella-like deployable structure to serve as a hypersonic decelerator. The ADEPT aeroshell drag surface is a 3-D woven carbon fabric that serves as a thermal protection system (TPS) and as a structural surface that transfers aerodynamic deceleration forces to the underlying ribs. The ADEPT structural skeleton is made up of four primary structural elements: main body, nose cap, ribs, and struts. An image of ADEPT is shown in Figure 1. The central nose cap is constructed much like a conventional rigid aeroshell. Its shape is a sphere-cone that provides the transition to the faceted pyramid shape of the deployed carbon fabric aeroshell. The nose cap is typically covered with an ablative TPS. The ribs provide the framework that supports the tensioned carbon fabric. The ribs are hinged at their attachment to the nose cap and are supported via struts at a point along their span that is compatible with structural and deployment mechanism requirements. The struts that support the ribs are installed in pairs to carry the aerodynamic loads transmitted from the carbon fabric and ribs back to the main body lower ring. The pairing of struts also provides lateral stability, torsional stability, and improved folding of the ADEPT structure. The aerodynamic surface is formed by tensioning 3D-woven carbon fabric over the ribs of the structural skeleton. High-purity intermediate modulus carbon fiber yarn is used to create a membrane that serves as the structural surface and the thermal barrier. The high temperature capability of the carbon cloth allows it to operate at high temperatures seen during entry (1500°-2000° C). Several of the top layers of the carbon fabric are allowed to oxidize and recede away during the entry heat pulse, but the construction of the 3D woven fabric allows the deployable aeroshell to maintain its structural integrity.

Sounding Rocket Flight Test of ADEPT at ~ 1m scale: A recent major development highlight was the sounding rocket flight experiment of the SmallSat scale ADEPT, called ADEPT SR-1, successfully launched on Sept 12, 2018.[2] The flight experiment utilized many features intended for 1-meter scale space flight missions such as the carbon-fabric decelerator, two-stage spring system for deployment, and a payload geometry approximating a 3U CubeSat. The ADEPT SR-1 was the first fight test which matured ADEPT in the areas of deployment and structural integrity and improved aerodynamic knowledge of the ADEPT open-back configuration. When considered with all the previous ground test and analysis products for the ADEPT project, successful demonstration of the SR-1 flight test Key Performance Parameters (KPPs) supports a

technology readiness level (TRL) claim of 5 for SmallSat scale ADEPT at the system-level.

The ADEPT team built and tested a 2m diameter ground test article to demonstrate deployment reliability and was evaluated for the delivery of a 1mT lander at Venus at 6m scale. That study demonstrated ADEPT can save considerable mass as well as maintain a low g-load during entry to accommodate sensitive instrumentation. More recently, wind tunnel and arc jet tests were performed prior to the SR-1 flight test to support smaller scale ADEPT applications for Mars as well as Venus.

ADEPT has been studied for a variety of Entry, Descent, and Landing (EDL) mission applications at Mars. The low ballistic coefficient, hypersonic deployable decelerator offers the potential for effective global access for landed payloads, overcoming the challenges of relatively high elevation landing sites currently inaccessible to higher ballistic coefficient entry systems. The stowable, packaging efficiency can enable multiple, network lander systems to be considered. Since ADEPT deploys prior to atmosphere entry, it also can significantly simplify EDL operations, possibly even delivery of robust landed payloads without parachutes or additional decelerators.

Small Sat Application and Drag Modulated Aerocapture: In addition to Mars EDL applications for ADEPT, there has been renewed focus on SmallSat orbiter missions using the aerocapture technique for orbit insertion.[3] One version of aerocapture is called Drag Modulated Aerocapture (DMA) which has been the focus of significant research and development in the last five years, focused on developing a simple and cost-effective atmospheric control method that is implementable on a small spacecraft within the constraints of a SIMPLEx-class mission. The simplest form of drag modulation aerocapture is the single-stage discrete-event architecture shown in Figure 2. The spacecraft enters the atmosphere in a high-drag/low-ballistic coefficient configuration with its drag skirt deployed, and then transitions to a low-drag/high-ballistic coefficient by jettisoning the drag skirt. The timing of the drag skirt jettison event is determined by a control algorithm with input from an onboard inertial measurement unit. The algorithm monitors the deceleration of the vehicle and triggers the release of the drag skirt based on predicted atmospheric exit conditions that result in capture to the target orbit. This form of drag modulation flight control provides the control authority needed for an interplanetary science mission with a simple enough implementation to be integrated as part of a small spacecraft.

Conclusion: The ADEPT deployable entry system is folded during launch and then deployed prior to atmospheric entry, enabling the entire flight system to be packaged into an ESPA compatible volume, meeting SIMPLEx and other mission launch and configuration constraints. The ADEPT system is uniquely capable as it can tolerate relatively high heating and pressure environments for deployable systems. ADEPT benefits from significant recent development, culminating in a successful suborbital flight test which demonstrated key aspects of the technology, including the ability to deploy in space and withstand aerodynamic loading during reentry. This has given an improved understanding of the flight system capabilities and benefits for a wide range of EDL and Aerocapture Low Cost Mars science mission applications.

References:

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[2]Cassell, A. M., et al "ADEPT Sounding Rocket One Test Overview" AIAA Aviation Conference, Dallas, TX, 17-21 June 2019.

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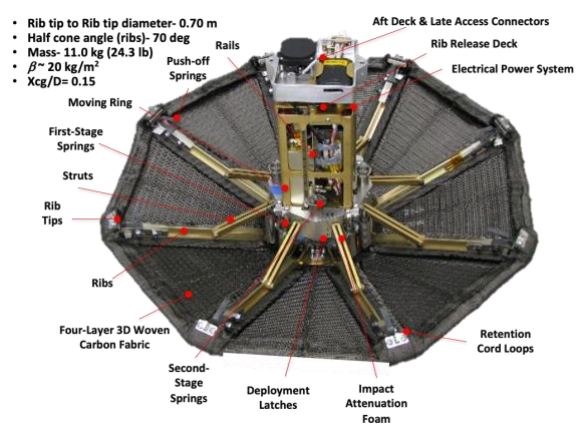

Figure 1. ADEPT SR-1 Vehicle Description

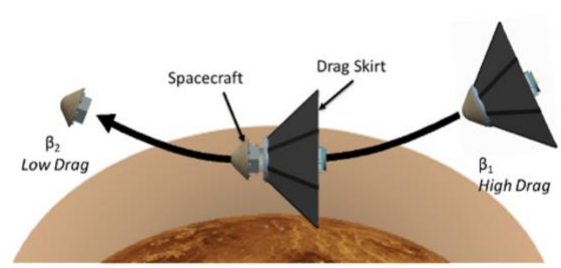

Figure 2. ADEPT Drag Modulated Aerocapture