**MECHANICALLY-DEPLOYED HYPERSONIC DECELERATOR AND CONFORMAL ABLATOR TECHNOLOGIES FOR MARS MISSIONS.** E. Venkatapathy[1], P. Wercinski[2], R. Beck[2], K. Hamm[2], B. Yount[2], A. Makino[2], B. Smith[2], P. Gage[3], G. Allen[4], D. Prabhu[4], [1]Corresponding author, NASA Ames Research Center, Moffett Field, CA 94035 (ethiraj.venkatapathy-1@nasa.gov), [2]NASA Ames Research Center, Moffett Field, CA 94035, [3]Neerim Corp., NASA Ames Research Center, Moffett Field, CA 94035, [4]ERC Inc., NASA Ames Research Center, Moffett Field, CA 94035

**Summary:** The concept of a mechanically deployable hypersonic decelerator, developed initially for high mass (~40 MT) human Mars missions, is currently funded by OCT for technology maturation. The ADEPT (Adaptive, Deployable Entry and Placement Technology) project has broad, game-changing applicability to *in situ* science missions to Venus, Mars, and the Outer Planets. Combined with maturation of conformal ablator technology (another current OCT investment), the two technologies provide unique low-mass mission enabling capabilities otherwise not achievable by current rigid aeroshell or by inflatables.

If this abstract is accepted, we will present results that illustrate the mission enabling capabilities of the mechanically deployable architecture for: (1) robotic Mars (Discovery or New Frontiers class) in the near term; (2) alternate approaches to landing MSL-class payloads, without the need for supersonic parachute or lifting entry, in the mid-term; and (3) Heavy mass and human missions to Mars in the long term.

**Introduction:** The grand challenge for EDL is in landing heavy mass systems needed for human exploration of Mars [1]. The 70° sphere-cone rigid aeroshell, used in all US Mars missions since Viking 1, limits landed mass to low elevation (MOLA) locations with the dependence on current supersonic parachute technology.

To roadmap the development approach for landing ~40 mT on Mars for human exploration, NASA sponsored an extended study called EDL-SA [2]. This study considered several new technologies – inflatable decelerators in the hypersonic and/or supersonic regimes, supersonic retro-propulsion, etc. – in various combinations to establish the feasibility of landing 40 mT, and made recommendations on how these technologies would feed into future Mars missions [3].

One technology overlooked by the EDL-SA study was the mechanically deployable decelerator, which can be stowed in the launch vehicle and deployed on orbit. Mechanically deployable decelerators were part of another NASA-sponsored study called TEST (Transformable Entry Systems Technology) [4]. The unique features of these large diameter (> 23 m) umbrella-like decelerators (Fig. 1) were: (1) custom woven carbon cloth, which when draped over a composite ribbed structure, served as both a load carrying structural member and a thermal protection system; (2) a gimbaling system for the heatshield to modulate lift; and (3) the ability to invert the umbrella-like heatshield into a configuration with landing legs. These mechanically deployable decelerators were shown to be very competitive (in terms of both mass and performance) with their large diameter inflatable counterparts [4].

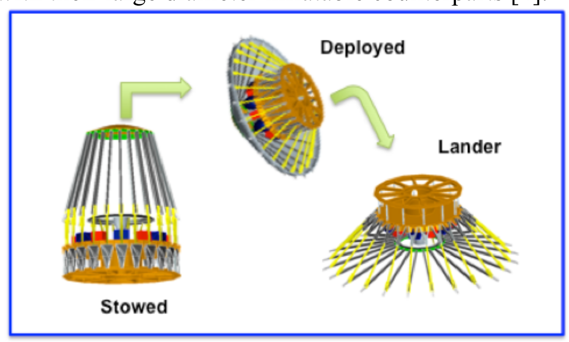


***Figure 1. TEST configuration a) under stowed, b) deployed prior to aerocapture and entry, descent phases and c) transformed into a landing configuration.***

***ADEPT:*** The valuable lessons learned from the TEST paper study led to investment by the Game Changing Development Program of the NASA OCT into developing the mechanically deployable decelerator technology for flight applications in the 6-12 m diameter scale called ADEPT. ADEPT achieves low ballistic coefficients (< 50 kg/m$^2$) via mechanical deployment of a low area, relatively low areal mass carbon fabric – rib structure. As shown in numerous EDL studies, this results in low peak heating rates, low peak deceleration experience high in the planet's atmosphere [5]. This benefits in lower risk TPS certification, the use of science instruments that would otherwise not have flown because of difficulties with flight qualification due to high g-loads, and for Mars – opening up the entire planets' surface for exploration since landed elevation is no longer a significant constraint on the ADEPT EDL architecture.

ADEPT, currently in its first of a two-year OCT funded effort, is focused on: (1) development of a sub-scale ground test article using flight-like 3D woven carbon fabric (2) characterization of the thermal and structural performance of carbon cloth at heat high loads and pressures and for various weaves and thicknesses, (3) mission suitability studies for a variety of planetary exploration destinations.

***Conformal/Flexible Ablators***. NASA OCT has also invested in the development of a new generation of ablative materials for thermal protection [6]. The new materials are either conformable (can be molded) or flexible, and are currently being arc-jet tested to establish their performance up to 250 W/cm$^2$.

The feasibility of a combination of ADEPT and conformable ablator technology is currently being explored for a future mission to Venus [7].

***ADEPT enabling low-g planetary entry.*** Using an 11.6 km/s ballistic entry of 2100 kg into Venus atmosphere, results of 3DOF trajectory simulations with various entry flight path angles are shown in Fig. 2. For each of the trajectories, key EDL performance parameters are also listed in the figure. The intent is to show the key benefit of shallow entries – reduction in g-load to enable *in situ* science. In addition, the results provide target environments (heat flux and pressure) in the development of new classes of mid-density TPS materials, with the added benefit of being able to test these materials in ground-based facilities.

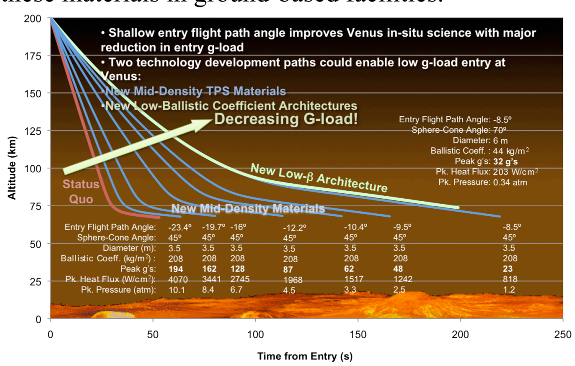


***Figure 2. 3DOF trajectories and EDL performance parameters for 2100 kg ballistic entry into Venus atmosphere.***

***ADEPT enabling Mars global surface access.*** The objectives of the present paper are to explore: (a) infusion of mechanically deployed hypersonic decelerator technology for Mars missions; and (b) infusion of lightweight conformable/flexible ablator technology.

Sample results of a quick 3DOF study for ballistic entries (ballistic coefficients of 22, 44, 88 kg/m$^2$) are shown in Fig. 3. Early design in the ADEPT project will show that these ballistic coefficients can be realized through the use of attaching a mechanically deployable decelerator to an aeroshell enclosing the payload. Deploying a low-risk sub-sonic parachute is feasible and provides access higher landed elevations at Mars.

Figure 4 lays out a timeline for the adoption of mechanically deployable decelerators for Mars missions. Having ground tested the concept, the intent is build a flight heritage through sounding rocket tests and atmospheric entry tests through 2016-2018. There is confidence that the technology will be ready for Mars and Venus missions in the 2020-2021 timeframe. In the longer term, assuming further demonstrations at Mars, the technology will be scaled up for eventual human exploration of Mars.

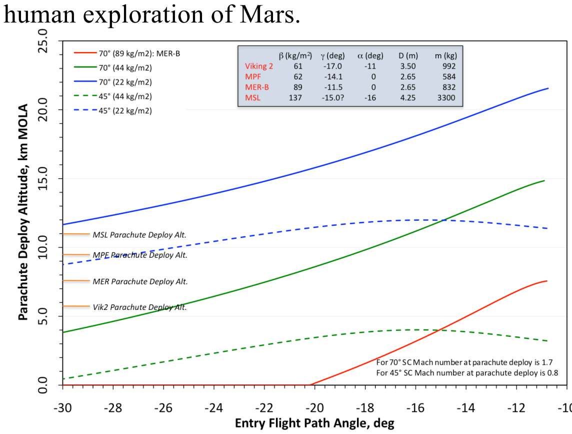


***Figure 3. Parachute deployment altitudes for low ballistic coefficient entries into Mars atmosphere for various entry angles. Ballistic coefficient lower than 88 kg/m$^2$ (MER-like value) provide higher altitude for parachute deployment. Subsonic deployment is possible with 45° sphere-cones.***

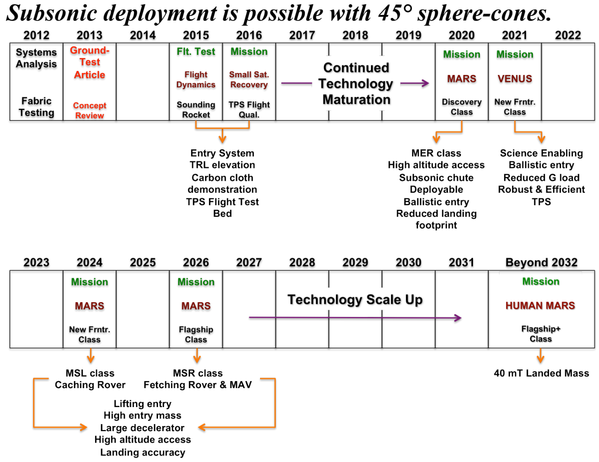


***Figure 4. Proposed timelines for infusion and maturation of mechanically deployable hypersonic decelerator technology in a Mars program for eventual human missions.***

**References:**

[1] Braun, R.D. and Manning, R.M., (2007), *JSR*, **44**(2), pp. 310-323. [2] Dwyer-Cianciolo, A. *et al.*, (2010), NASA/TM-2010-216720. [3] Dwyer-Cianciolo, A. *et al.*, (2011), NASA/TM-2010-217055. [4] Venkatapathy, E. *et al.*, (2011), AIAA-2011-2608, Dublin, Ireland. [5] Venkatapathy, E. *et al.* (2011), IPPW8, Portsmouth, VA, USA. [6] Arnold, J. *et al.*, (2011), IPPW8, Portsmouth, VA, USA. [7] Venkatapthy, E. *et al.* (2012), IPPW9, Toulouse, France.