ENABLING VENUS IN SITU MISSIONS USING MECHANICALLY DEPLOYED AERODYNAMIC DECELERATOR. S. J. Saikia[1,2], H. Saranathan[1,2], M. J. Grant[2], and J. M. Longuski[2], [1]Graduate Student, [2]School of Aeronautics and Astronautics, Purdue University, West Lafayette, Indiana 47907-2045, [1]sarag@purdue.edu.

Introduction: The 2013 Planetary Science Decadal Survey recommends a Venus In Situ Explorer as the highest priority in the New Frontiers class missions [1]. The gaps in the knowledge of the atmosphere to understanding climate evolution on Venus requires in situ measurements of deep atmospheric gas compositions and surface mineralogy using landers and atmospheric probes.

Challenges of Venus Aerocapture and Entry: Venusian atmosphere represents a harsh entry environment to spacecraft. All past missions to Venus employed a rigid aeroshell and a thermal protection system composed of fully dense Carbon Phenolic (CP), constrained by the diameter of the payload fairings of the launch vehicles. For ballistic flight, the properties of CP necessitates the spacecraft enter the atmosphere at a steeper flight path angle. Such entry trajectories result in high heat fluxes (3–17 kW/cm^2) and high deceleration (150-500g's) [2]. A mechanically deployed aerodynamic decelerator, known as the Adaptive Deployable Entry and Placement Technology (ADEPT) is a viable entry system alternative to the 45° sphere-cone rigid aeroshells for in situ missions to Venus. ADEPT reduces both the peak deceleration loads and peak heat fluxes as opposed to traditional aeroshell technology.

Guided Aerocapture and Entry Using ADEPT: Very low ballistic coefficient (<30 kg/m^2) and shallow entry flight angle (γ) combinations for ADEPT help in reduction of peak deceleration loads (to tens of g's) and peak heat fluxes (less than 100 W/cm^2) using a 6 m / 70º diameter ADEPT-VITaL configuration for ballistic entry. A mass savings of 248 kg is achievable using ADEPT compared to baseline VITaL rigid aeroshell with mass of 1061 kg [3]. ADEPT also presents attractive options of precision control of spacecraft for any stage of the mission via:

β-control: by changing reference area (angle of ADEPT skirt deployment)—akin to opening and closing of an umbrella. Figure 1 shows the maximum- and minimum-β configurations for a given mass at zero angle of attack.

Angle-of-attack and bank angle control: A gimbaled aeroshell [4] and movable ADEPT aerodynamic surface presents ways to control the angle of attack and bank angle or both.

The peak deceleration load for ADEPT-VITaL was found to be 30 g's or more [4]. In the proposed paper, we present results of studies of an trajectory space parameterized by entry velocity, entry flight path angle, ballistic coefficient (deployable decelerator size), and vehicle control. We present optimal solutions for guided entry using ADEPT that carry the spacecraft from entry conditions to subsonic parachute deployment altitude of around 60 km. The solution minimizes the total heat load by constraining the peak heat flux to under 120 W/cm^2, and peak deceleration to less than 10 g's.

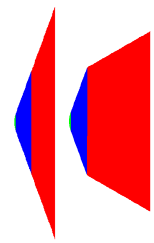

Figure 1. ADEPT geometries for two β-configurations: fully deployed (minimum-β) and ADEPT skirt angle of 45º (maximum-β) on the right. Blue color represents the 70º sphere-cone forebody and red cone represents the deployable decelerator portion.

Shallow-γ increases the probability of skip-out of the spacecraft due to various perturbations (atmospheric) and uncertainties in the states; but in ADEPT, the ability to control the deceleration mitigates this problem. We explore the advantages of β, angle-of-attack, and bank angle control methods to provide precision control of the spacecraft from entry to landing in the presence of uncertainties. The same techniques can be used for Venus aerocapture problems.

Summary: Use of active control during aerocapture and entry increase the accessibility of Venusian surface, atmospheric, and orbital targets for scientific investigations. Precision control of the spacecraft during all mission phases enables the delivery of scientific payloads at interesting targets. The advantages of guided aerocapture and entry using ADEPT provide additional reduction in the structural and instrument mass (free up mass for more instruments or thermal control masses) to enhance longetivity for a mission.

References: [1] Squyres, S., et al. (2011), NAP Press, pp. 111-132. [2] Dutta S. et al. (2012) IEEE AC, 10.1109 [3] Smith B. et al. (2013) IEEE 978-1-4673 [4] Venkatapathy E. (2011) AIAA 2011-2608.