Cubesat Application for Planetary Entry (CAPE) Missions: Micro-Reentry Capsule (MIRCA)

Jaime Esper
NASA Goddard Space Flight Center, Greenbelt MD 20771
Email: Jaime.Esper@nasa.gov

The Cubesat Application for Planetary Entry Missions (CAPE) concept describes a high-performing Cubesat system which includes a propulsion module and miniaturized technologies capable of surviving atmospheric entry heating, while reliably transmitting scientific and engineering data. The Micro Return Capsule (MIRCA) is CAPE's first planetary entry probe flight prototype. Within this context, this paper briefly describes CAPE's configuration and typical operational scenario, and summarizes ongoing work on the design and basic aerodynamic characteristics of the prototype MIRCA vehicle. CAPE not only opens the door to new planetary mission capabilities, it also offers relatively low-cost opportunities especially suitable to university participation.

Keywords: Cubesat, planetary entry micro probe, CAPE, MIRKA2, RICA TPS material

Introduction

So far, no microprobe (less than 10 kg) has entered another planetary atmosphere and successfully relayed data back to Earth. Although the Deep Space 2 Mars microprobes did reach their destination (total mass about 6.5 kg each), unfortunately they were lost due to a combination of delivery system failures and other unknown factors. This paper describes a planetary entry probe based on the widely popular Cubesat-class spacecraft specification (Cubesat Application for Planetary Entry Missions, or CAPE probes). Within a science operational context, CAPE probes may be sent from Earth to study a celestial body's atmosphere, or to land on some high-value target on its surface. Either one or multiple probes may be targeted to distributed locations throughout the geographic landscape and could be released systematically and methodically from an orbiting spacecraft. CAPE microprobes would each have its own propulsion, and hence would be capable of targeting regions identified by the mother ship as high-interest. This enables a completely new capability for science not possible with traditional "drop-and-flyby" schemes. To supplement its flexibility, each probe would incorporate a communications architecture that provides a high-level of assurance its precious data is acquired and transmitted back to Earth for analysis.

CAPE

CAPE consists of two main functional components: the "service module" (SM), and the "planetary entry probe" (PEP). The SM contains the subsystems necessary to support vehicle targeting (propulsion, ACS, computer, power) and the communications capability to relay data from the PEP probe to an orbiting "mother-ship". The PEP itself carries the scientific instrumentation capable of measuring atmospheric properties (such as density, temperature, composition), and embedded engineering sensors for Entry, Descent, and Landing (EDL) technology monitoring and assessment. Figure 1 illustrates the complete CAPE system in its flight configuration. The total system mass is less than 5 kg. The solar array generates about 17W at 1 AU, and the system nominally consumes about 11W of power.

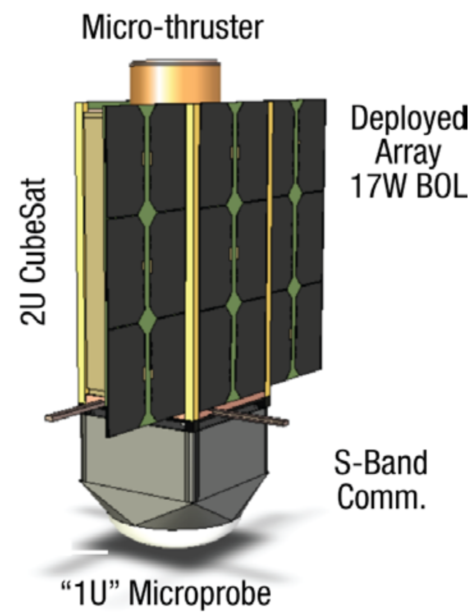

Figure 1: CAPE in its deployed configuration.

Figure 2 shows a generic CAPE operations concept, from system deployment to probe release and entry into a given planetary atmosphere. Three mission phases are identified: 1. Deployment, 2. Targeting, and 3. Planetary Entry. In the deployment phase the vehicle rides inside a standard Poly Picosatellite Orbital Deployer (P-POD) MkIII (or equivalent), and is released by the mother-ship in a prescribed drop-off orbit. This drop-off orbit is adjusted in a way that ensures atmospheric entry within the capabilities of CAPE's thruster system, but at a safe altitude for the mother-ship. During the targeting and orbit adjustment phase, CAPE uses its own thrusters to slowly target a particular entry corridor. Since entry dispersion is expected to be large, a “ground track” path (or great circle on the planet’s surface), rather than a specific spot is targeted. The final mission phase is planetary entry. At this time, the SM is maneuvered to allow for a slightly delayed entry from the PEP. PEP to SM cross-link communications will ensure data is relayed to the orbiting mother ship. Since the SM will be trailing behind the PEP, it will go through communications blackout after the probe has completed its entry phase, and hence will be capable of relaying a full set of probe scientific and engineering data. The SM will continue to relay communications until it burns up in the atmosphere.

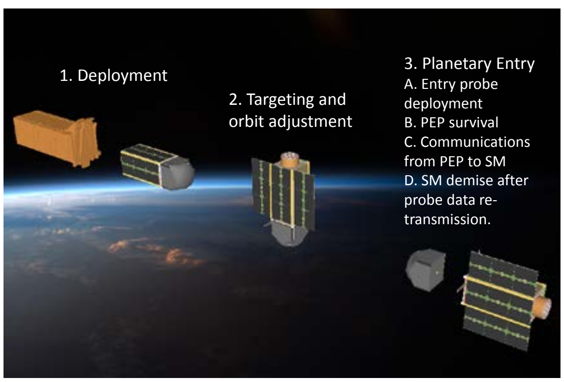

Figure 2: CAPE typical mission phases.

MIRCA

In order to reduce CAPE’s implementation risks, a PEP re-entry demonstrator is currently being designed and prototyped at the NASA Goddard Space Flight Center (GSFC). MIRCA is expected to validate key system technologies, including advanced miniaturized sensors and supporting technologies. The prototype also serves to establish geometric and mass properties required to analyze its aerodynamic performance under varying flight regimes. Preliminary results are presented.