ChipSat Mars Atmosphere Explorer (ChipSat-MAX). B. Streetman,[1] S. George[2], and L. Singh[3],
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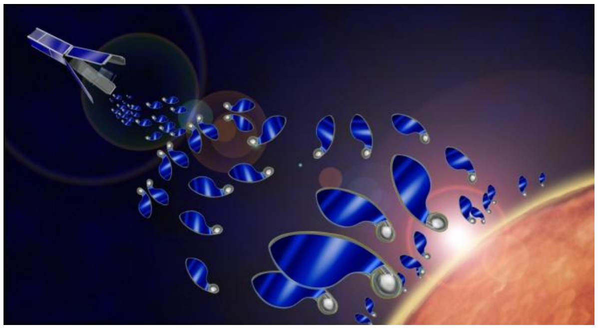

Introduction: Chip-Scale Satellites (ChipSats) present a novel, differentiating technology that can revolutionize light-weight *in situ* atmospheric surveys. Exploiting the physics of the ChipSats' small physical scales and large area-to-mass ratios enables high-density *in-situ* measurements of the Mars atmosphere during descent and landing from orbit. Deploying a large number of ChipSats with simple atmospheric sensors yields a distribution of both spatial and temporal measurements of the atmosphere of interest. We propose a campaign of study beginning with the analysis and design of a ChipSat reentry platform eventually leading to survey missions to Martian and Outer Planet Moon atmospheres.

Motivation: The ChipSat-MAX platform has the potential to survey, sample, identify and track priority materials and ambient characteristics the Martian atmosphere while creating a technology that paves the way for future large landers and opens new mission opportunities not available to traditional spacecraft. The ChipSat-MAX concept reduces what previously would have represented an entire large-scale mission payload to the size and cost of a single traditional science instrument.

Potential Scientific Impact: One of the four highest priority goals outlined by the 2010 Mars Exploration Program Analysis Group (MEPAG) Goals Document is the characterization of Mars' atmosphere, climate, and climate processes [1]. A clear finding of the MEPAG study is that this characterization necessitates long-term, repeated sampling of the atmosphere at appropriate spatial and temporal scales. Mars Global Surveyor and other orbiting assets have generated substantial atmospheric information; however, because they are constrained to remote sensing, little data exists about the Mars planetary boundary layer. There are limited near-surface meteorological data sets from previous landers, and while the upcoming Mars Science Laboratory will provide a substantial amount of additional data, all sources will still have insufficient resolution in time and space to validate global or mesoscale atmospheric models. Validation of these models is critical to the determination of the short- and long-term processes (daily, seasonal and solar cycle) that govern distributions of water, carbon dioxide, and dust in the Mars atmosphere.

Potential Technology Impact: The NRC has identified *precision landing* and *increased mass-to-surface* as key technologies for future robotic and human NASA exploration missions [2]. Previous Mars EDL studies [3] have shown that the largest source of landing dispersions on Mars, driving the need for increased control authority and propellant mass allocation, is the uncertainty in air density and wind magnitude. Suitable data for validation of relevant atmospheric models would provide a significant improvement in guided reentry performance and increased total payload mass fraction on guided systems. Studies have also shown that a priority for increasing mass to the surface of Mars is the use of aerocapture and aerobraking technology. The success of these techniques depends on accurate knowledge of atmospheric properties.

The ChipSat-MAX design presents the capability to realize NASA's goals in both the above categories.

Concept: Studies of a true chip-scale spacecraft began with researchers at Cornell University [4]. In a ChipSat, all the typical subsystems of a spacecraft (Attitude Control, Communications, Power, Thermal, etc.) are integrated into a single component the size of microchip, i.e. ~2cm x 2cm x 50μm, weighing 100mg. Draper Laboratory and Cornell have collaborated to design a core ChipSat "bus" based on Draper's expertise in Multi Chip Module (MCM) construction and highly miniaturized electronics. The compelling advantage of such micro-scale satellite technology stems from the realization that the forces that govern the physics of flight of these low-length scale devices is markedly different to those of more conventionally scaled space systems. These effects render a micro-scale system naturally survivable to thermal or physical shock during atmospheric reentry [5], and capable of real-time sensing at all trajectory points.

We propose an arc of development leading to eventual missions to extraterrestrial atmospheres. In a ChipSat-MAX mission, a cloud consisting of a large number of ChipSats is deployed in an entry trajectory from a Cubesat-scale tender. The ChipSat cloud is

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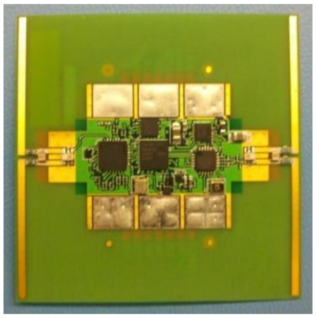

Figure 1. Current ChipSat Bus

equipped with an array of sensors measuring basic information about the atmosphere through which it is travelling; an individual ChipSat might contain no more than one simple sensor. As the chips are dispersed and fall relatively slowly through the atmosphere, both spatial and temporal resolution of measurements is achieved. The chips are capable of relaying their measurements to the tender spacecraft.The ChipSat-MAX project will consist of four project phases. Phases I and II will focus on tailoring the current ChipSat architecture to atmospheric sampling missions and validating with terrestrial data collection. Phase III would send ChipSats to Mars, and potentially Phase IV to another planetary body.

Phase I: Analysis and design of a reentry ChipSat based on the core architecture developed by Draper Labs and Cornell University, tailored to *in situ* atmospheric sampling. Design of drag body, modeling and simulation of reentry, and sensor selection would be completed.

Phase II - Earth Mesosphere Mission: Develop and prototype the Cubesat deployment spacecraft. Build a representative number of reentry ChipSats for launch from either a sounding rocket or LEO orbit. The benefits of such a mission are two-fold: (1) Validate system design and concepts in a lower-cost forum that can be heavily instrumented for telemetry collection and performance monitoring. (2) Gather useful scientific data about Earth's Mesosphere during reentry.

Phase III - MicroSat Mission to Mars: Building upon the Earth-based validation mission, a mission to Mars would characterize the next phase of ChipSat development. Leveraging the delivery and deployment mechanisms developed and evaluated in Phase II, a small, low-cost mission will be designed. It could either ride as a hosted payload on another larger spacecraft, or be launched cheaply as a secondary payload. Experiments performed in Phase-II will be repeated from Mars orbit, with the deployment spacecraft similarly inserted into a low-altitude Mars orbit and releasing ChipSats in a reentry trajectory. The ChipSat bus elements would operate identically during descent to the Phase II Earth Mesosphere Mission. Such a mission could revolutionize our knowledge of the Martian atmosphere and provide the scientific and technologic advances discussed above, at a fraction of the cost of a traditional interplanetary mission.to refine and validate Martian atmosphere models.

Phase IV: Outer Planet Moon Atmosphere Exploration – Incorporate the mature ChipSat-MAX platform as an "instrument" on a flagship mission to an outer planet. The delivery mechanism would be deployed from a larger craft to deliver a payload of ChipSats to a moon with significant atmosphere.

Figure 2. ChipSat-MAX Development Arc

Potential Impact: The game-changing aspect of the ChipSat-MAX concept is that the entire suite of sensors, entry bodies, and data collectors take on the cost and mass of a single traditional science instrument.The potential exists to study any atmosphere (including our own), at a lower cost and with greater impact. A cloud of sensors distributed in both space and time allows for measurement of the dynamics of an atmosphere in addition to its base state. Along with scientific gains, proper understanding of the Mars atmosphere realizes NASA's long-term technology goals and paves the way for next-generation precision entry, descent, and landing systems.

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