DAS-CUBES – INDEPENDENT EMITTER/RECEIVER CUBSESAT CONFIGURATION FOR PLANETARY ATMOSPHERIC MEASUREMENTS. Cassandra Sands[1], Adam Huang[2], Ed Wilson[3], Yupo Chan[4], [1]Arkansas Center for Space & Planetary Sciences, 346 Arkansas Ave, Fayetteville, AR 72701. cmsands@email.uark.edu. [2]University of Arkansas Dept. of Mechanical Engineering, 204 Mechanical Engineering Building, Fayetteville, AR 72701. phuang@uark.edu. [3]Harding University, 915 E. Market Street, Searcy, AR 72149. [4]University of Arkansas Dept. of Systems Engineering, 2801 S University Ave. Little Rock, AR 72204.

Introduction: At the University of Arkansas, the authors are introducing a state of the art, low cost atmospheric detection platform, referred to as the Diurnal Atmospheric Surveyor CubeSats (DAS-Cubes). The spacecraft system concept is a novel technology that has the unique ability to control the spatial and temporal resolution of measurements by dictating the distance and direction between spacecraft. Because the spacecraft system exhibits diurnal operational capabilities, atmospheric measurements would no longer be subject to the current limitations inherent to the reliance on stellar and solar occultations. The DAS-Cubes concept is being developed as part of a series of CubeSat projects by the ARKSAT team at the University of Arkansas. The satellite system will be tested and demonstrated in Low Earth Orbit, using the ISS as a launch platform with an expected launch date in 2020.

Background: Extraterrestrial measurements of atmospheres, as well as other phenomena of interest to planetary science, such as plumes and ejecta, are largely limited to stellar and solar occultations. While this method can be powerful in some applications, it has a number of drawbacks and limitations. Atmospheric measurements gathered via occultations are restricted to limb measurements only, often have very short data acquisition times, and are dependent on the alignment of the stars rather than being a parameter within the control of a project team in order to achieve specific science objectives. Additionally, stellar occultations are unable to detect certain chemical species due to absorption of certain wavelengths by interstellar dust clouds, and can introduce complexities into sensing equipment[1]. While cubesats and other small satellites have primarily been used for Earth-orbiting missions, the recent use of the MarCo spacecraft (Two 6U Cubesats used for data transmission) as part of the InSight mission to Mars, as well as the planned INSPIRE mission to demonstrate the functionality of cubesats in deep space continue to make a strong case for cubesats as being capable of achieving objectives on an interplanetary scale[2].

Spacecraft & Instrument Concept: The DAS-Cubes is a set of independent spacecraft, one with an emitting light source (DAS-E, emitter), another with a receiver and tracking capabilities (DAS-C, chaser), that together are capable of achieving high quality spectroscopic measurements of atmospheric or other material in between the two spacecraft. The concept, if successful, would greatly expand our ability to measure planetary atmospheres, search for biosignatures indicative of extraterrestrial life, and study other media such as plumes and ejecta, comet trails, and asteroid dusts.

The concept has two initial phases planned for development and testing: ARKSAT-1 (expected launch late 2019) will demonstrate the emitter portion of the spacecraft system, and ARKSAT-2 will comprise the paired emitter/receiver system. In addition to the DAS-Cubes system, the ARKSAT-2 mission will also test a new low cost, water-based, non-toxic, non-pressurized micro-propulsion system (CubeSat Agile Propulsion System, CSAPS), to augment the ongoing exploration of new propulsion systems for cubesats[3]. Figure 1 shows an illustration of the DAS-Cubes in spaceflight, with multiple spacecraft capable of providing measurements in as many degrees of freedom as is required by a particular mission.

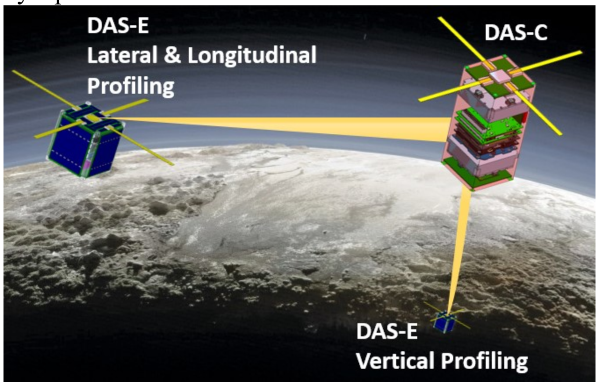

Figure 1: Illustration of DAS Cubes, highlighting the flexibility of independent spacecraft. Base image [4].

Applications to Planetary Science: The DAS-cubes concept would be a useful tool for studying other planetary bodies in the solar system. This could include comets, asteroids, dwarf planets, extraterrestrial atmospheres, and plumes such as those observed on Enceladus during the Cassini mission. Much of the compositional information on atmospheres and plumes obtained on previous missions has been done using a combination of stellar and solar occultations, resulting in initial compositional constituents. However, future explorations interested in more detailed atmospheric data would benefit from larger datasets. For example, at Enceladus, the Cassini mission had two planned stellar occultations. Each provided around 100 seconds of data, and were limited by the weak stellar signals[1]. Now that many atmospheres or other media have base information on chemical makeup, emitters for specific missions could be designed to be full spectrum or to target specific wavelengths, and thus give more accurate measurements of particular species. Multiple types of emitters and sensing equipment would allow for measurements at multiple frequencies. Near infrared measurements of CO_2, H_2O, and CH_4 on Mars would give vertical profiles of these species, some of the most important for studies of the Martian atmosphere. Detailed study of Mars' atmosphere is currently being done with a combination of general circulation models and spectroscopic data limited to stellar occultations. This study could be greatly improved and expanded by the use of the DAS-Cubes concept.

Measurements that are also of great interest for further study in our solar system are chemical compounds that may indicate the presence of organisms on other planetary bodies. While astrobiology has been a part of our considerations for exploration in our solar system for decades, both the discovery of complex organic compounds in the plumes of Enceladus as well as the strong evidence of global subsurface oceans on icy moons of gas giants such as Europa and Enceladus have revitalized and narrowed our searches for life in our solar system to a handful of likely candidates. Even missions that are currently in the planning stage, such as Europa Clipper, are intending to rely exclusively on stellar and solar occultations for plume measurements[5]. As we continue to search for life elsewhere in our solar system, it would be beneficial to investigate and develop new platforms for the types of measurements we can make.

Future Work: As part of the process of developing this technology to achieve high quality science data, there are several key parameters that will need to be investigated. The spacecraft will need to achieve a certain pointing accuracy at both the emitter and the receiver spacecraft in order to achieve meaningful measurements. There will also be a certain required concentration threshold of chemical species to be able to be detected with this technology, determined by the spectrometer used on the chaser satellite, as well as the distance between satellites. The testing of the DAS-Cubes system in Low Earth Orbit as part of the ARKSAT-2 project will allow for assumptions and technical rationale relevant to the system's functionality to be validated and refined.

There are some known or expected limitations to the use of this technology. While these techniques would not have to account for planning stellar or solar occultations, the converse may be true. The extent to which stellar occultations of certain brightness may interfere with these measurements will be investigated. A threshold of brightness for stellar occultations to avoid given the baseline distance between emitter/receiver will be quantified as part of the in-orbit testing of the system. Although this technology may eliminate the need for additional complexity in sensing equipment, it will likely add a small, but not insignificant amount of weight and complexity to spacecraft or a planned mission; either with entirely separate spacecraft, or with deployable cubesats. Finally, successful use of this system may be dependent upon increased propulsion capabilities for cubesats. This is an ongoing topic of research. As of 2017, two missions have flown with new cubesat propulsion systems, and many more have been tested in the lab [6].

Conclusions: A successful paired dynamic emitter/receiver spacecraft system able to achieve high quality data would expand our horizons for low cost technology platforms, allow a deeper understanding of planetary atmospheric composition and dynamism, and aid in search for extraterrestrial life. To achieve global atmospheric measurements and spatial and temporal resolution of measurements on another planetary body will require much longer data acquisition times than has previously been accomplished and could be greatly augmented by the flexibility of an independent spacecraft with a light source of known intensity, spectrum, and source distance. The DAS-Cubes system is intended to investigate the applicability of this spacecraft concept to other bodies in the solar system, as well as ultimately demonstrate some of these capabilities in Low Earth Orbit.

As part of the 50th LPSC, the DAS-Cubes spacecraft system, ARKSAT-1 and ARKSAT-2 missions, the CSAPS propulsion system, and technical details on a concept of operations (CONOPS) for a mission to Enceladus will be presented.

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References: [1] Hansen, C., and Esposito, L. et. al. (2006) *Science, 311,* 1422-1425. [2] Schoolcraft, J, Klesh, A. T., et al. SpaceOps Conference (2016) *AIAA.* [3] Lee, J., Huang, P. IMECE (2018) *ASME.* [4] NASA/JHUAPL/SwRI. (2015) *New Horizons Mission.* [5] McCoy, K., and Nairouz, B. et. al. (2018) *IEEE,* 1-13. [6] Lemmer, K. (2017) *Acta Astronautica, 134*, 231-243.