Active SpecTROmeter for Small Satellites (ASTROSS). Samuel Cano[1], Cassie Sands[1], Charles Smith[2] and Adam Huang [2] [1]University of Arkansas Center for Space and Planetary Sciences 332 N. Arkansas Ave, Fayetteville, AR 72701(scano@uark.edu) [2]University of Arkansas Mechanical Engineering Department 863 W. Dickson Street, Fayetteville, AR 72701 (phuang@uark.edu)

The ARKSAT Cube-Satellite Missions will be the first student-led satellites in the state, and the initial spaceflights were conceived as preliminary demonstrators of technology development in pursuit of the Active SpecTROmeter for Small Satellites (ASTROSS) System. ASTROSS features one or more co-orbiting pairs of CubeSats, one emitting light (ARKSAT-3E) and one chasing and receiving the light (ARKSAT-3C), that together form a system capable of making spectroscopic measurements of the atmosphere at Low Earth Orbit altitudes. The proposed ASTROSS system would demonstrate its feasibility as a low-cost, active spectroscopy platform with potential for use in future planetary missions [1]. The ARKSAT-1 and ARKSAT-2 are CubeSats that were designed, developed, and are currently the first student-built satellites in the state at the University of Arkansas. ARKSAT-1 is a 1U CubeSat that aims to test a deorbiting module, ground tracking capabilities, and gather initial atmospheric measurements, and is the first demonstration of successful flight and operations. It was selected under NASA's 8th CubeSat Launch Initiative, delivered in December 2022, and is manifested on the SpaceX-27 Mission launching out of Kennedy Space Center on March 2nd, 2023. ARKSAT-2 is the follow-up 2U CubeSat that builds off of the design and operational successes of ARKSAT-1 and is expected to be deployed via ISS in 2024. ARKSAT-2 will be the first operational demonstrator of the novel CubeSat Agile Propulsion System (CSAPS) which utilizes Propylene Glycol, a water-based, non-toxic, non-flammable, and non-pressurized propellent that offers thrust on the order of mNs for attitude and altitude control [2]. It also features a more advanced tracking and chasing ability to further investigate thrust and control requirements for future formation flights.

ARKSAT-3 is a research collaboration between three Arkansas universities with UA as the lead institution and aims to be the follow-on technology demonstration needed for the ASTROSS system, featuring a 1.5U and 3U CubeSat pair (ARKSAT-3E and ARKSAT-3C) for which ARKSAT-1 and ARKSAT-2 were analogues for. The University of Arkansas is tasked with developing the more complex ARKSAT-3C and all the engineering units, while providing expertise to Harding University and John Brown University for the building of -3E units.

It will feature an innovative Calibrated Free-Space Spectroscopy (CFSS) instrument onboard the pair of CubeSats in formation flight [3]. Most in-situ measurements can only represent a limited environment, usually the sample is taken within the instrument onboard a satellite or rover making it difficult to gather data on larger or planetary scale.

ASTROSS aims to address this and other issues by splitting the emitting and receiving ends of a spectrometer onto two satellites, allowing for a scanning-like mechanism of measurement where the atmosphere between the two satellites is sampled at a calibrated distance. The system would ensure proper separation distance between the emitting and receiving satellite pair during formation flight by way of a novel onboard Low Temperature Co-fired Ceramics Electric Thruster (LTCC-ET) on ARKSAT-3C for orbital maneuvering. The LTCC manufacturing process involves stacking individual layers of soft ceramic-polymer thick films containing patterned geometries and vertical interconnects, much like PCBs, which are further filled with electrically conductive pastes. Once the layers are stacked, they are clamped at high pressures ranging from 2000 to 4000 psi, followed by co-firing at 850 – 1000 °C to fuse all the layers together. This would be the first electric thruster enabled by LTCC manufacturing technology, allowing for the parallel fabrication of all the internal subsystems including the ionization / plasma cavity, excitation electrodes, and accelerating electrodes to produce a monolithically-integrated electric thruster.

This allows new in-situ measurement capabilities currently non-existent in current space research. The system could continuously sample the atmosphere as the pair of satellites orbit a planetary body in formation flight leading to the development of a more compressive map of the entire atmosphere of a planetary body, achievable in a fraction of time and budget compared to previous small satellite instruments. Our preliminary analysis of global coverage of planetary bodies using ASTROSS, indicate that atmospheric coverage of 10km resolutions will only take on the order of a few months to accomplish for bodies such as Venus, Mars, and Titan. Potential studies on Venus could include measuring sulfur compounds that act as tracers for atmospheric dynamics and potential volcanism, water and its role in Venus's present chemical processes as well as the HDO/H2O ratio, aerosols formed by photochemical processes, and other phenomena of interest like its retrograde orbit, low rotation speed, and super-rotation in its upper atmosphere. Mars is the most studied planet in our solar system besides Earth, ASTROSS could provide direct measurements in the near infrared of vertical profiles of CO2, H2O and CH4, three of the most important molecules in the Martian atmosphere. On Titan there is still to be learned about the processes of the Methane\Ethane cycle, ASTROSS would be instrumental here by developing a global atmospheric map.

The success of ARKSAT-3 demonstration would also allow for multiple emitting satellites to contribute to the system in a more complex flying formation. Here, the receiving satellite could collect laser signal from up to three emitting satellites on a co-orbiting path. This system would allow for simultaneous measures along the longitudinal and lateral paths of orbit as well as over different altitude with an emitter below. The ASTROSS system would also have the ability to tackle more niche in-situ studies including sample processes related to atmospheric cooling on the ecliptic side of an orbit. ASTROSS was selected for a NASA EPSCoR grant in 2022 and is expected to be developed in the next three years. The concept will initially be launched into Low Earth Orbit where its atmospheric measurements can be validated against established data from National Oceanic and Atmospheric Administration's series of GOES satellites.

References:

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