Atmosphere and Plume Explorer (APEX) CubeSat Study

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Introduction
This study was performed by a group of largely undergraduate students to determine the utility and viability of placing a nano-satellite (CubeSat) onboard the Europa Clipper spacecraft proposed to be launched by NASA in 2021. The main Clipper craft will perform 45 flybys of Europa over a 3-year period, performing several kinds of scientific experiments (mass spectrometry, magnetic mapping, imaging, and more). By including onboard a separate small spacecraft additional science goals can be achieved. The spacecraft proposed here will perform both atmospheric science using a mass spectrometer and radiation dosimetry using a set of modified SRAM chips.

Mission Drivers
Radiation
Space around Jupiter features an intense radiation environment, which would kill a human in a matter of seconds if it opened directly. The maximum Total Ionizing Dose (TID) for this mission was set to 1 Mrad, as most radiation-hardened components are rated to this level. To enable the spacecraft electronics to survive this environment, about 2.5 mm of aluminum shielding will cover all critical spacecraft areas.

Communications
Due to the small size of the spacecraft and the distance form Earth, direct communication back to the surface is impossible. The large antennas and high power levels required simply do not fit inside a satellite smaller than a briefcase. Instead, data will be relayed back to Earth through the Europa Clipper spacecraft.

Power
Due to the low level of solar intensity at Jupiter, a large solar array is required to power the spacecraft. Options featuring small nuclear power sources were ruled out due to the current political environment.

Concepts
A number of notional mission profiles were developed to satisfy the mission constraints. First a set of 3 CubeSat Units (10 cm x 10 cm x 30 cm) sized spacecraft were considered. Due to the large volume of components required to keep the satellite alive in the Jovian environment, this option was found to be infeasible. A notional APEX spacecraft design showing the extension of the components outside of the maximum volume.

Continuing Hurdles
Cold Temperatures
The Jovian environment is significantly colder than those encountered by a typical CubeSat. Most electronic components are rated to approximately -40°C, and the current APEX model shows temperatures in the range of -70 to -90°C.

Proposed Architecture
The final proposed option for the APEX architecture features the 6U spacecraft detaching from the Europa Clipper spacecraft upon arrival in the Jovian system. The APEX craft will then perform a number of flybys in conjunction with Clipper performing relative science. At the end of the mission lifetime, the CubeSat will dive to Jupiter’s first moon, Io, and sample its volcanic plumes. A final swing by the Europa Clipper craft will allow APEX to fully transmit all of the data obtained from this flyby.

The spacecraft features a propulsion system encompassing 2 out of 6 total CubeSat units. The spacecraft has a set of deployable solar arrays, which will provide the power to all spacecraft systems, as well as the heaters that keep the critical components functioning.

Conclusions
This study has developed a notional method for extracting additional science from an existing proposed NASA mission. The mission profile developed in this study provides valuable additional science while not adding significant risk or complexity to the main mission.

The proposed addition of an Io flyby allows for the collection of scientific data that will not be obtained by the Io Volcano Observer (IVO) spacecraft (which would not fly if Europa Clipper is funded). This augmentation in capabilities is a large cost save, as IVO had an expected mission cost of $450 million, compared to the $10 Million.

With a launch in 2021 much work still needs to be completed to turn the APEX CubeSat into reality, but as the notional project timeline below suggests, there is still sufficient time to prepare a spacecraft for launch prior to the launch of the Europa Clipper mission.

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