Atmosphere and Plume Explorer (APEX) CubeSat Study

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Overview
Introduction
Students at the University of Illinois at Urbana-Champaign conducted a study to determine the utility and viability of placing a nano-satellite (CubeSat) onboard the Europa Multiple Flyby Mission spacecraft proposed to be launched by NASA in 2021. The main Europa Mission will perform 45 flybys of Europa over a 3 year period, performing several kinds of scientific experiments (mass spectrometry, magnetic mapping, imaging, and more). The Atmosphere and Plume Explorer (APEX) spacecraft will augment the mission science goals by separating from the primary spacecraft and performing independent atmospheric science using a mass spectrometer and radiation dosimetry. Not only will this science be performed at Europa, but an additional Io flyby allows for the collection of scientific data that would only be obtained by another full mission travelling to the Jovian system. By including this small satellite, additional science data from Europa and Io will be collected thereby decreasing the risk for future Jovian missions.

Adaptable Suite of Trajectory Options
The APEX craft will perform a number of flybys of Europa in conjunction with Europa Mission, allowing it to perform independent science which can be relayed back to Earth via the primary satellite’s systems. At the end of the mission lifetime, the CubeSat will divert to Jupiter’s first moon, Io, and sample its volcanic plumes. A final swing by the Europa Mission craft will allow APEX to transmit all of the data obtained from the Io flyby.

The overall set of trajectory options identified through this study is highly adaptable to the specifics of the particular mission. Trajectories including variable numbers of Europa and Io flybys have been identified, giving a range of different potential mission risk postures.

Proposed Spacecraft
Compact Main Bus
The final proposed option for the APEX architecture features the 6U spacecraft detaching from the Europa Mission spacecraft upon arrival in the Jovian system. The spacecraft features a propulsion system occupying two CubeSat volume 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.

Powerful Instrumentation
The instrument performing the most groundbreaking science onboard (mass spectroscopy) is the Neutral Ion Composition of Atmospheres (NICA) developed at the Naval Research Laboratory. This instrument will provide additional insight into the speed and composition of the atmospheres of both Europa and Io, which in the case of Io will lead to a completely unique set of scientific discoveries. It is based on the Winds Ions Neutrals Composition Suite (WINCS) which has flown on several Earth orbiting missions. Also included will be a suite of dosimeters to better characterize the Jovian radiation environment.

Key Findings
Radiation Mitigation
The Jovian system radiation is a key driving mission factor. APEX has been built with components that can tolerate a maximum Total Ionizing Dose (TID) of 1 Mrad. To further improve the survivability of the spacecraft electronics, at least 2.5 mm of aluminum shielding will cover all critical spacecraft areas, reducing the lifetime TID to the tolerable level.

Realistic Propulsion Outlook
The APEX architecture focuses on minimizing propellant requirements to allow for maximum payload mass. A commercial hydrazine system is used (seen in the middle of the spacecraft on the exploded view to the right), and a total Δv of only 200 m/s is required to perform the most ambitious of the trajectory options identified.

Unique Communications Architecture
Due to the small size of the spacecraft and the distance from Earth, direct communication back to the surface is impossible. A primary UHF radio will be used while in close proximity to the primary craft at Europa, while a high power X-band antenna will relay data during the return from Io.

Diagram showing the proposed mission profile of the APEX spacecraft (trajectory shown in light blue) away from the Europa Mission spacecraft (light green).

A model of the APEX spacecraft with side panel removed.

NICA instrument cutaway showing the path of travel for ions being analyzed.

A model of the proposed APEX spacecraft showing the intended configuration of components.

Front of the APEX spacecraft showing X-Band patch antenna.