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 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). **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.

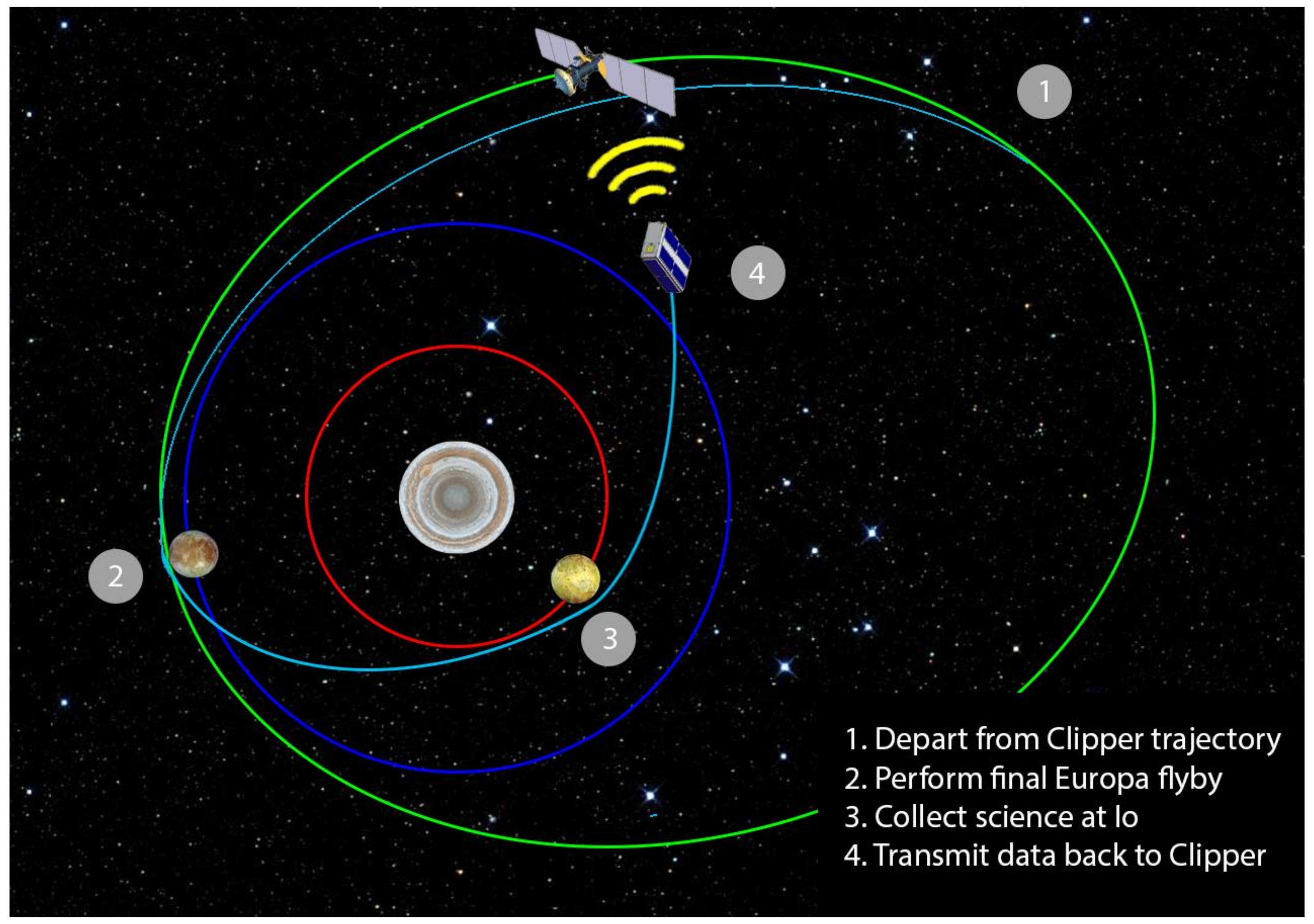
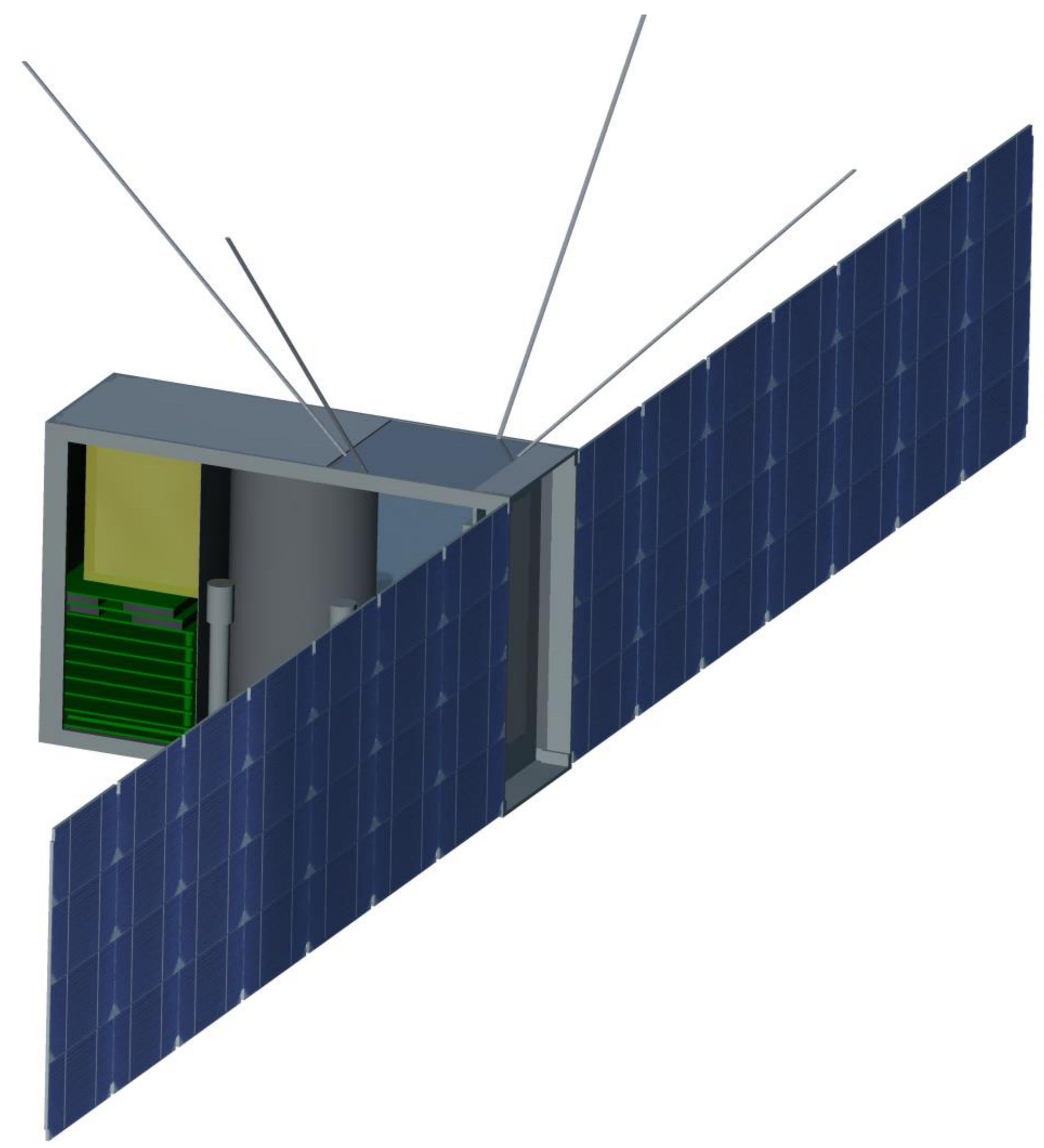


Diagram showing the proposed mission profile of the APEX spacecraft (trajectory shown in light blue) away from the Europa Mission spacecraft (light green).

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.

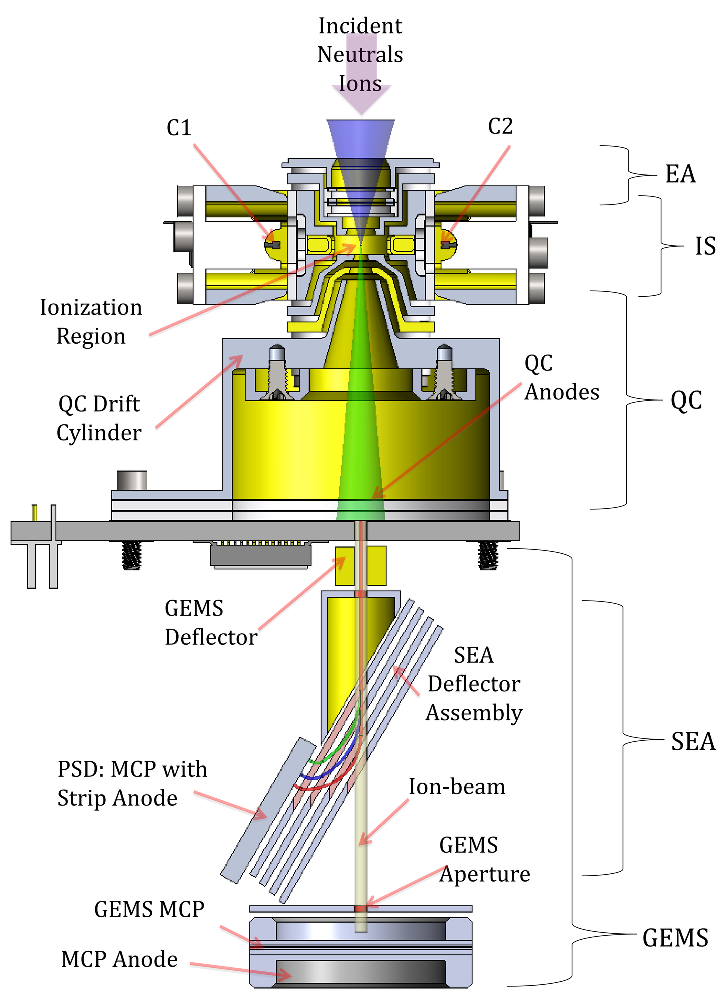


A model of the APEX spacecraft with side panel removed.

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.

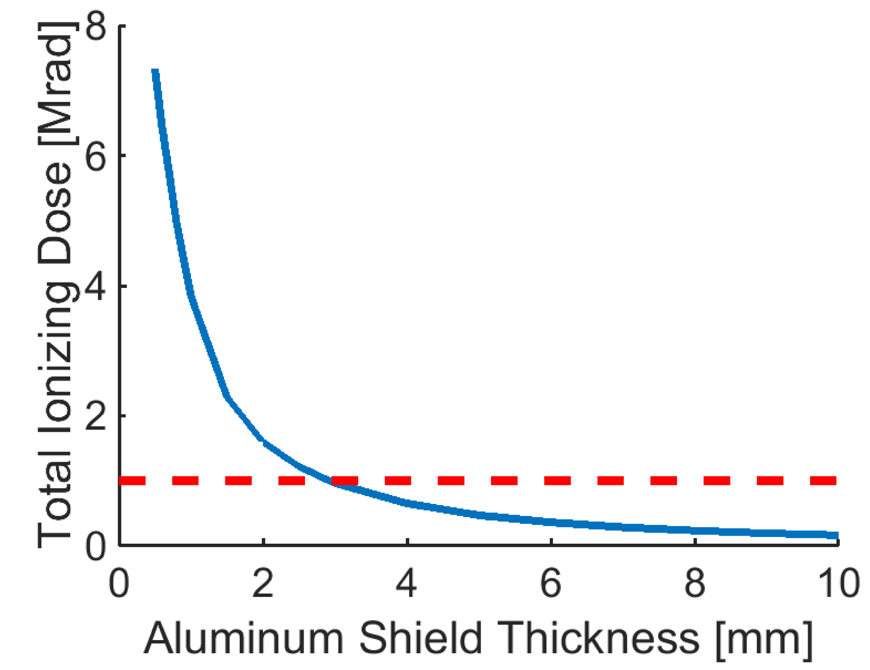


NICA instrument cutaway showing the path of travel for ions being analyzed.

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.

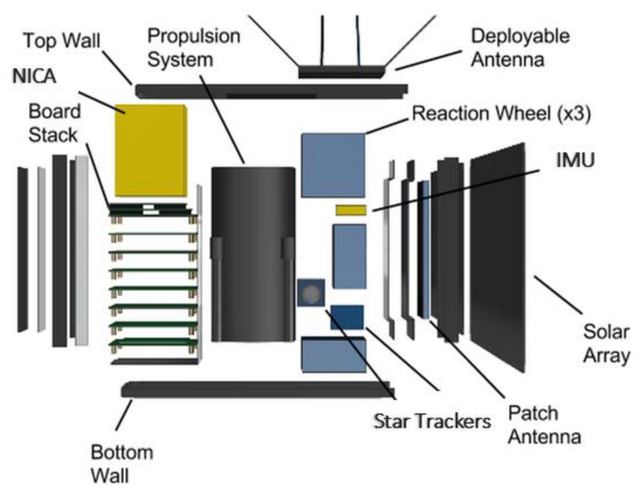


Plot showing the effectiveness of aluminum shielding in the Jovian radiation environment. The 1 Mrad TID cutoff dosage is shown as a red horizontal line.

Moon	Io	Europa
Total Ionizing Dose Per Flyby [krad]	383.1	48.9
Required Δv Per Flyby [m/s]	30.9	6.6
Average Time Between Flybys [days]	27.5	15.4
Science Time [seconds]	278.5	327.2

Realistic Propulsion Outlook

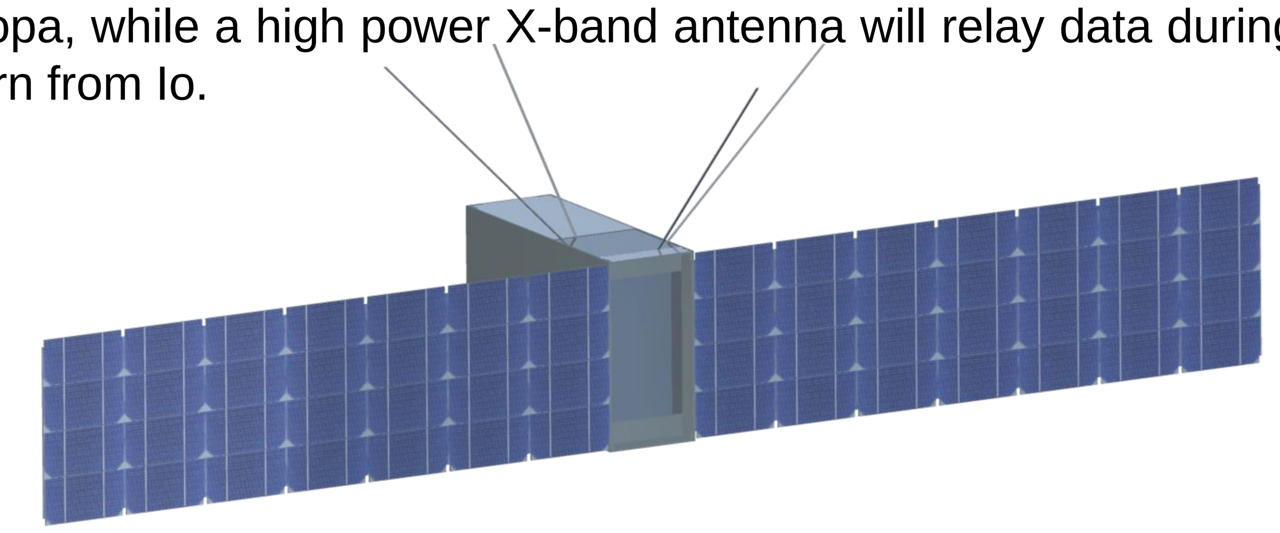
The APEX architecture focuses on minimizing propellant requirements to allow for maximum payload mass. A commercial hydrazine system is used (seen in the middle of the spacecraft on the exploded view to the right), and a **total Δv of only 200 m/s is required** to perform the most ambitious of the trajectory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



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

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.



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