Passive Hybrid Thermoplastic Graded-Z Radiation Shielding for a Europa CubeSat Mission

Nicolas Gutierrez (nag4@uw.edu), Robert Winglee, Ian Johnson, Paul Sturmer, Paige Northway

Abstract
The Advanced Propulsion Laboratory at the University of Washington is conducting a concept study for a 3U CubeSat to be launched on NASA's Clipper mission to perform magnetic field measurements around the Jovian moon Europa. The primary concern with electronics surviving in Jupiter's orbit is withstanding the high energy and high density radiation fields that exist throughout the planet, with beta particles being in highest flux. Typically, satellites on Jovian missions are spot shielded with high proton density metals to protect sensitive electronics from radiation induced damage. This study will analyze and test a number of existing graded-Z shield compositions and new hybrid thermoplastic graded-Z shields. A graded-Z shield is a type of passive radiation protection in which layers of material are placed in a gradient from low to high proton density, with a thin final layer of low proton density material. Preliminary calculations show that substituting the aluminum portion of the graded-Z shield with crystalline polypropylene will both increase shielding capabilities and lower total shield mass. This new Z-shield designed at the Advanced Propulsion Lab will have a hybrid composition with both metal and thermoplastic layers. The test itself will be conducted by exposing a custom built Arduino based Geiger counter to a beta particle source and assessing five test articles including the new hybrid shield as well as traditional shields. Due to the non-linearity and complexity of radiation interactions with matter, different shields may be more effective at blocking different particle energies.

Theoretical Background
In 2012, NASA began planning for a mission to Jupiter's icy moon, Europa. The purpose of the mission is to take a variety of specific measurements of the moon ranging from magnetic field readings to topographical imaging. Advanced Propulsion Lab (AP) would provide a supplemental CubeSat to accompany NASA's Clipper spacecraft and assist in measuring Europa's (magnetic) field. The CubeSat would take a measurement, store the data on an onboard memory module and transmit the data to the Clipper for final transmission to Earth. Compared to Earth's Van Allen belts and intra-solar radiation levels, Jupiter's radiation environment is significantly stronger in relation to other parts of the solar system. Radiation flux density exceeding 180P (protons cm^-2)s^-1 of 10 MeV energies and 10^7 (electrons cm^-2)s^-1 of 1 MeV energies.

Data
A critical point of this study is supporting data that a Graded-Z shield is more effective at blocking beta radiation than a traditional slab shield and supporting the replacement of aluminum in the Z-shield with polypropylene. The following graphs created from NIST data shows the theoretical reasoning behind the replacement.

Experiment
The experiment itself will be conducted by simulating a to some extent the radiation field that the Cubesat would possibly encounter near Europa. Since this study focuses on beta radiation as the primary issue, an experiment was designed to test the effectiveness of the shields against high-energy electrons. For this radiation sources of Thallium-204 K beta particles was used which produce 7 MeV beta particles at approximately 1 micro Curie activity and 2 MeV beta particles at 0.1 micro Curie activity respectively. The experiment will quantify the performance in three areas: beta radiation shielding, Bremsstrahlung production, and Bremsstrahlung effect shielding. The most effective shield will have the lowest, weighted combined counts per minute (rpm) of beta particles and Bremsstrahlung rays at a Geiger counter. In order to differentiate between beta particles and Bremsstrahlung rays, two Geiger-Muller tubes will be used. One that is sensitive to high energy photons and one that is sensitive to both beta particles and high energy photons. This will allow us to know which type particle caused a "hit" to register on the counter.

Anticipated Results
The ultimate goal of this study is to present and qualify an alternative to expensive radiation hardened electronics for the Europa Cubesat. If the designed hybrid graded-Z shield can sufficiently protect the payload from radiation while also falling within mass and volume limitations, then fewer radiation hardened components will have to be used. This will save a large amount of money due to the high price of radiation hardened components, which can be anywhere between 100 to 10,000 times more expensive than their commercial counterparts. This study hopes to show that for beta radiation energy levels within one order of magnitude of 1 MeV, that a graded-Z shield is 65% more mass effective at shielding when compared to a traditional slab shield, and that the new hybrid graded-Z shield is between 10-15% more mass effective than a regular graded-Z shield.

Sources and Acknowledgements
Dr. Michael McCarthy — for assistance with the Geiger-Muller tube and its support electronics and with data interpretation.