Advancing Asteroid Science and Technology Using Student Built CubeSat Centrifuge Laboratories

Jekan Thangavelautham[1], Erik Asphaug[2]

[1]Space and Terrestrial Robotic Exploration (SpaceTREx) Laboratory
Aerospace and Mechanical Engineering Department
University of Arizona

[2]Lunar and Planetary Laboratory
University of Arizona

Asteroid science, technology, and exploration is an important and exciting research and education theme at the UA that encompasses the College of Science and College of Engineering. For example, the UA's Catalina Sky Survey has been instrumental in discovering a large fraction of known Near-Earth Asteroids. In addition, the UA leads the OSIRIS-Rex mission (PI: Dante Lauretta)—a sample-return mission to the Near-Earth Asteroid, Bennu. These ongoing achievements make the UA an ideal institution to lead an effort in STEM education that creates excitement and instills a sense of adventure and discovery to a diverse community of minority students in the local community. UA is planning to develop a research and education center called ASTEROID (Asteroid Science, Technology and Exploration Research Organized by Inclusive eDucation (ASTEROID) funded by NASA.

This proposed program envisions project-centric, hands-on education that would place UA students and transfer students from the nearby Pima Community College and the University of Puerto Rico, Humacao in cutting-edge research labs at the UA and in direct collaboration with a NASA Center. UA, Pima, and Univ. of Puerto Rico students would be tasked with developing an exciting series of CubeSat missions particularly CubeSat centrifuge laboratories AOSAT 2 through 4. They will use the student-built AOSAT-1 as the template. On AOSAT-1 minority students made-up 50% of the team and was representative of local demographics. These on-orbit labs will be built and operated by students and they will simulate asteroid surface conditions and will be used to advance the science and technology of asteroids.

The students will use AOSAT 2 through 4 to test their hypothesis. These on-orbit centrifuge laboratories will be on the frontlines to advance asteroid science and technology. AOSAT 2 will perform hypothesis testing of impact studies on a simulated asteroid surface. This will result in the formation of artificial craters and their characterization over accelerated time. In AOSAT 3, the focus will be on manipulation of the simulated asteroid surface through excavation, grappling, and anchoring activities. AOSAT 4 will be used to demonstrate excavation and processing on a simulated asteroid and to extract water for production of rocket propellant. The water may be heated into steam or electrolyzed into hydrogen and oxygen and combusted. The on-orbit centrifuge platform will enable accelerated development and testing of critical In-situ Resource Utilization technology to extract water on asteroids and turn them into propellant for transiting spacecraft.

The longterm strategic vision of the center is to facilitate the development of low-cost, UA-led small-satellite and CubeSat exploration missions to Near-Earth Asteroids, planetary moons, and comets. This is being led by an interdisciplinary team of graduate Master's students, Ph.D. students, and postdocs at UA's College of Engineering and College of Science. In pursuit of this long term effort, rapid advancements are being made using automated missions design tools to design whole new missions including single and multiple (swarms) of spacecraft to perform tours of asteroids and Kuiper Belt Objects (KBOs). The capability is being replicated with robotics to enable end to end multidisciplinary design and control optimization for extreme environment exploration tasks. Another focus area is on unconventional spacecraft architectures including hybrid orbiter/landers such as SPIKE, inflatable spacecraft, and landers to perform multiple surface examinations and seismic readings of small bodies. A third focus area has been the development of a diverse 'toolbox' of miniature landers, hoppers, and impactors scaled to tackle varying high-risk/high-reward exploration goals. These landers are meant to be dropped off from passing spacecraft to perform short-duration missions to characterize the small body surface and layers beneath covered due to weathering. Impactors are being designed both to clear a surface and remain as a beacon for secondary science missions. A fourth focus area has been to advance the Cislunar economy and to find ways to utilize the natural resources on nearby asteroids and moons and their strategic locations for assembly of next-generation telescopes, fuel depots, critical communication relays and deep space spacecraft repair/servicing and assembly centers. System architecture development is complemented with basic research in new forms of solar and laser-based additive manufacturing and robotic assembly.

These factors make asteroid science, technology, and exploration an exciting vehicle for hands-on education of minority students. Our past efforts have shown that involving new students in front-line research projects helps bring out student creativity, new and diverse ideas, and instill drive, purpose, and ambition. Working with UA, Pima and Univ. of Puerto Rico undergraduate students, in turn, helps graduate student mentors advance their leadership skills, get teaching experience, and sharpen their research efforts. Importantly, the proposed program educates students through hands-on, motivational skills and experience—an experience that will enable them to open doors to opportunities in the high-tech science and technology sectors and meet NASA education goals by strengthening the future workforce for NASA and the nation.