TEXAS SPACECRAFT LABORATORY

THE UNIVERSITY OF TEXAS AT AUSTIN COCKRELL SCHOOL OF ENGINEERING

OCELOT

The **O**rbital **C**amera for **E**stimation of **L**and-based **O**ptical **T**argets (OCELOT) is a new mission, in partnership with NASA JSC, graduate researchers at UT Austin, and the TSL. OCELOT was one of the proposals selected to move forward in the NASA Smallsat Technology Partnerships Appendix. The proposal was selected to move forward in spring 2020, and the next phase of the mission officially commenced on July 1st, 2020. The current phase of the mission is scheduled to run till spring 2022.

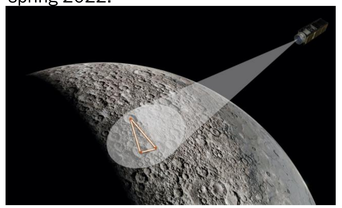


Figure 1: By identifying crater patterns, OCELOT will be able to estimate its position in real time

Mission Objectives

OCELOT's aims to develop positioning, navigation, and timing (PNT) capabilities by tracking surface features. The project objectives to mature the algorithms used in surface-feature tracking for use on a 3U cubesat, as well as create a mission and satellite bus design for an on-orbit demonstration in Low-Earth Orbit (LEO). TSL's specific role in the mission will be to develop the mission and bus design through the preliminary design review (PDR) phase.

ARMADILLO

The Atmospheric **R**elated **M**easurements **A**nd **D**etection of subm**ILL**imeter **O**bjects (ARMADILLO) mission was the winner of the Air Force Research Laboratory's University Nanosatellite Program-7 competition in 2013. Students have been involved with the ARMADILLO mission from its proposal to its launch and operations. ARMADILLO launched on June 25, 2019 aboard SpaceX Falcon Heavy as part of the Space Test Program-2 (STP-2).

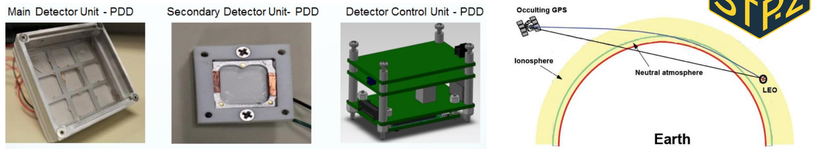


Figure 2: Two of the ARMADILLO payloads, the Piezoelectric Dust Detector (left), and FOTON GPS Receiver (right).

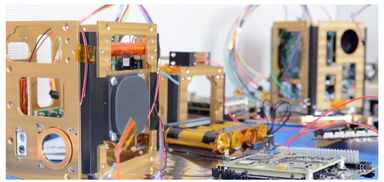


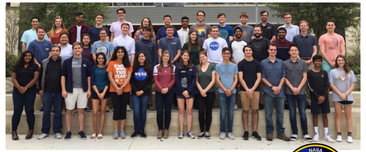
Figure 3: The ARMADILLO FlatSat on the TSL clean bench during student-led development and testing.

ARMADILLO Payloads

1. Piezoelectic Dust Detector (PDD): Developed by Baylor's CASPER lab, the PDD detects submillimeter space debris.
2. FOTON GPS Receiver: Developed in UT's own Radionavigation Lab, this dual frequency GPS receiver performs space weather experiments through radio occultations (**Fig 2**).
3. Retroreflector: Developed by NASA Ames, the retroreflector performs laser-ranging experiments.

Our Story

The Texas Spacecraft Laboratory (TSL) at The University of Texas at Austin was originally established in 2002 as the Satellite Design Laboratory by Dr. Glenn Lightsey. The TSL is a student-driven research laboratory, comprised of undergraduate and graduate students of many majors and areas of study, and is led by Dr. Brandon Jones. Our missions encompass all phases of the space mission lifecycle, from inception to launch and operations. The TSL actively collaborates with other university research groups, governmental organizations, and/or private industry to build spacecraft that perform scientific experiments or demonstrate new technologies.



Seeker Vision

Seeker Vision was a NASA JSC mission to build up autonomous visual inspection capabilities. The Seeker 3U CubeSat (**Fig 3**) launched in April 2019 aboard a Northrop-Grumman Enhanced Cygnus vehicle (**Fig 4**), and was deployed in Fall 2019 after the vehicle delivered cargo supplies to the ISS.

The TSL was engaged to build the machine learning and computer vision algorithms that enabled Seeker to identify Cygnus and estimate relative bearing (azimuth and elevation). The algorithms were required to run in real time on lightweight, low-power hardware. They used Google's TensorFlow to train a neural network to localize Cygnus in different orbital conditions, and the OpenCV library to estimate a more accurate centroid. (**Fig 5**).

After Seeker was deployed in Fall 2019, the TSL was also engaged to perform a post-flight performance analysis of the computer vision component of the mission. Following these results, NASA JSC is currently in the proposal stages for a second iteration of the Seeker Vision mission.

Figure 3: The Seeker and Kenobi 3U CubeSats, side by side. Image credit: NASA.

Figure 4: Northrop-Grumman Enhanced Cygnus Spacecraft. Image Credit: NASA.

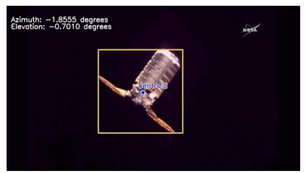


Figure 5: Seeker Vision algorithm applied to Northrop-Grumman Enhanced Cygnus spacecraft.

SERPENT

The **S**atellite **E**valuation of **R**elative **P**ose **E**stimation of a **N**on-cooperative **T**arget (SERPENT) mission is a winner of the Air Force Research Laboratory's University Nanosatellite Program-10 competition in 2018. TSL students wrote the proposal in Summer 2018, and have since passed numerous reviews. The next review SERPENT faces is CDR, slated to occur early 2021.

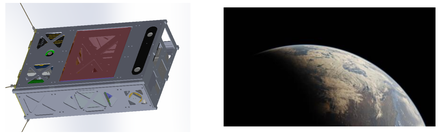


Figure 6: SERPENT Post-PDR CAD w/o Solar Panels and Rendered Earth

Figure 7: SERPENT ConOps Post-PDR.

Figure 8: Nvidia Jetson TX2i

SERPENT Experiments

1. Pose Estimation of Passive Target: The spacecraft will deploy a passive target, and will use a stereo camera to feed images and depth information to the pre-trained neural network running on the Jetson TX2i.
2. Jetson TX2i Performance in LEO: The spacecraft will run system benchmarks once the primary experiment is complete for as long as the TX2i is capable. Radiation based failures are of particular interest.

Seeker R&D

Following the Seeker Vision mission, the TSL was contracted for further research relating to on-orbit, deep learning-based computer vision.

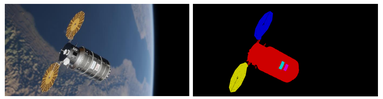


Figure 9: Synthetic data with label mask

Figure 10: Improved localization algorithms

Figure 11: Full pose estimation

Seeker R&D Research Areas

1. Realistic synthetic data generation using Blender
2. Full six-degree-of-freedom pose estimation of an uncooperative target based only on monocular images
3. Improvement upon the Seeker Vision algorithms for even faster and more robust spacecraft localization, applicable to a wider variety of conditions

Learn More

Learn more about the Texas Spacecraft Lab at https://sites.utexas.edu/tsl/, and find us @TexasSpacecraftLab on Facebook and Instagram.