NASAfacts

PY4

Four-CubeSat Swarm of PyCubed-Based Spacecraft

PY4 is a low-cost, rapid-turn-around, four-satellite technology demonstration based on the open-source PyCubed avionics framework. PyCubed is an open-source, radiation-tested CubeSat avionics platform that integrates power, computing, communication, and attitude determination and control functionality into a single low-cost module programmable entirely in the programming language Python.

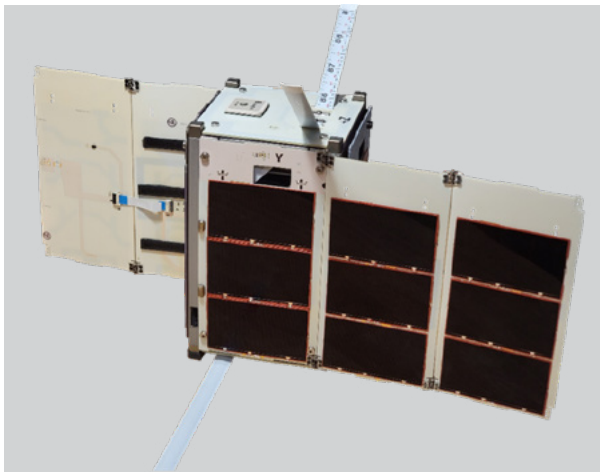
The goal of PY4 is to demonstrate low size, weight, power, and cost (SWaP-C) spacecraft-to-spacecraft ranging, on-orbit relative navigation, and coordinated simultaneous multi-point radiation measurements. By developing and demonstrating these technologies on a small scale, they can be implemented for future multi-spacecraft missions, enabling NASA to pursue its future science, technology, and exploration goals.

The four identical PY4 spacecraft periodically measure their relative distances to an accuracy of 1 meter or better by measuring the time-of-flight of radio packets exchanged between all spacecraft. These range measurements provide information about the relative positions of the spacecraft which, when combined with other sensor data, can be used to uniquely determine the configuration of the swarm. This on-board determination of the swarm's topology is achieved through use of low-cost commercial off-the-shelf transceivers leveraged from the prior NASA Small Spacecraft Technology program mission, V-R3x, that launched to low-Earth orbit on January 24, 2021.

The technologies developed for PY4 are relevant for future multi-satellite missions and other spacecraft platforms because they:

- Provide low key navigation capabilities to enable multi-satellite missions at with low SWaP-C
- Demonstrate coordinated multi-point measurements
- Demonstrate magnetorquer-only 3-axis attitude control that reduces the need for expensive reaction wheel actuators in small spacecraft
- Advance spacecraft communication technology with robust and fault-tolerant ad-hoc mesh networking among the four spacecraft nodes
- Advance flight-software capabilities by demonstrating over-the-air software updates, autonomous forwarding of software updates between spacecraft, and automatic storing-and-forwarding of ground commands among spacecraft in the swarm.

These capabilities are essential to enable cost-efficient mission operations, reducing the need for direct operator interactions.



PY4 engineering unit with solar panels deployed.
Credits: Max Holliday, NASA Ames

Mission Objectives

The PY4 Mission will:

- Demonstrate
  - On-orbit topology determination using S-Band time-of-flight ranging
  - Over-the-air software and firmware updates and command forwarding
  - Underactuated magnetorquer-only pointing

- Collect coordinated high-speed total ionizing dose radiation measurements
- Conduct onboard software-defined radio activities.
- Demonstrate drag-based formation flying as a stretch goal.

Fast Facts

- The PY4 swarm consists of four 1.5 unit (U) CubeSats.
- Once on orbit and operational, the CubeSats will will fly in a circular, sun-synchronous orbit slightly more than 325 miles (525 kilometers) above Earth.
- PY4 is the third CubeSat mission using the open source PyCubed avionics framework.
- PY4 is also the third collaboration between Carnegie Mellon University's Robotic Exploration Laboratory and NASA's Ames Research Center in California's Silicon Valley.
- A January 2024 launch is expected onboard the SpaceX Transporter 10 rideshare.

Partners

- PY4 is led by principal investigator Zachary Manchester, director of the Robotic Exploration Lab at Carnegie Mellon University (CMU), in Pittsburgh, Pennsylvania.
- NASA's Small Spacecraft Technology program within the agency's Space Technology Mission Directorate funds the PY4 mission. The program is based at NASA's Ames Research Center in California's Silicon Valley.
- NASA's Ames Research Center supports assembly, integration and testing of the CMU spacecraft through Max Holliday, creator and maintainer of the PyCubed framework.

Learn More

- PyCubed Project Page: http://roboticexplorationlab.org/projects/pycubed.html
- PyCubed hardware/software resources and tutorials: https://pycubed.org

For investigators

- Investigators interested in funding opportunities with the Small Spacecraft Technology program, please visit here.
- For technical inquiries about PY4, contact: arc-sst@mail.nasa.gov

For news media

- Members of the news media interested in covering this topic should reach out to the NASA Ames newsroom.

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FS-2023-07-01-ARC