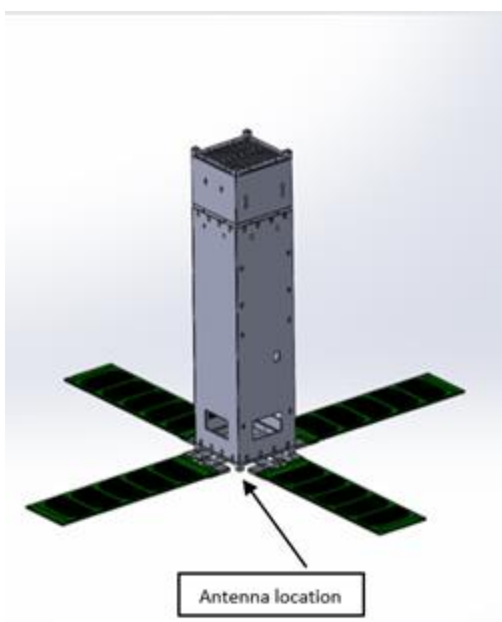
SOCRATES Satellite Technical Description

The primary mission of the Signal of Opportunity Cubesat for Ranging And Timing Experiment (SOCRATES) mission is to measure the arrival time of hard x-rays and soft γ-ray photon, to determine the potential of this method for signal-of-opportunity positioning, navigation and timing (PNT) in deep space. The secondary mission is to measure the x-ray photon energies and arrival times to study electron acceleration in solar flares. Both missions will use the Cesium Iodide Thallium-doped Incident Energy Spectrometer (CITIES). CITIES uses signals emitted by x-ray pulsars to measure the range of a space vehicle relative to some predefined origin. Eventually (after technology maturation) CITIES has the potential to be an integral part of a system used for three dimensional positioning and timing in deep space or other GPS/GNSS-denied operational scenarios.

The satellite will be launched as cargo aboard the NG-12 Antares International Space Station (ISS) resupply mission, from Wallops Flight Facility, October 19, 2019. It will be deployed from the ISS no earlier than April 2020, into an approximately circular orbit of about 400 km, on an inclination from the equator of 51.6 degrees. Transmission will begin 45 minutes after deployment, and operation will continue until de-orbiting. Atmospheric friction will slow the satellite and reduce the altitude of the orbit until de-orbiting, which is expected to occur less than 1 year after launch. See the Orbital Debris Assessment Report for details.

The SOCRATES spacecraft is a 3U Cubesat with the dimensions of 10 cm X 10 cm X 34.05 cm. The total mass is about 3.6 Kg.

Figure 1 SOCRATES Overview



The satellite systems are described below.

<u>Attitude Determination Control and Navigation (ADCN) subsystem:</u> The attitude determination system on SOCRATES fuses angular rate measurements from a triad of rate gyros (VectorNav VN-100) with vector measurements from a magnetometer triad (also VN-100) using an

Extended Kalman Filter (EKF). In addition to generating an attitude estimate, the EKF estimates the time varying rate gyro biases, which allows the system to coast for short periods of time without magnetometer vector measurements. The control system uses a CubeSpace magnetorquer triad. The navigation system uses a Novatell OEM 7 GNSS receiver, with a patch antenna on the zenith facing end. It generates an estimate of the satellite's position and velocity vectors at a rate of 1 Hz.

The attitude determination function on SOCRATES is based on defining one of two pointing vectors depending on the phase of the mission. In the primary or PNT mission phase, the vector points from the current position of SOCRATES to the pulsar in the Crab nebula. In the secondary or solar science phase, the position of SOCRATES relative to the sun is calculated. These vectors are calculated based on the position estimate of SOCRATES (generated by the GNSS receivers) and a model of Earth's position in its orbit around the sun. Knowledge of Earth's position requires a measurement of time which is provided by the GNSS receiver.

Command and Data Handling (CDH) Subsystem: The CDH system consists of a Beaglebone Black microcomputer running the space variant of the Goldy flight control system software, a state machine program developed at the University of Minnesota to support flight operations of autonomous vehicles. The space variant exploits sensors and operational conditions unique to spacecraft.

Radio and Communications (COMMS) Subsystem: The COMMS system utilizes the Aerospace Corporation Advanced Radio (ADV), operating in the 915MHz band. The patch antenna, also from Aerospace Corporation, is located on the nadir facing end of the spacecraft. The throughput rate varies from 1.2 - 500kbps depending on orientation and range. The Aerospace Corporation ground station network will support the mission.

Electrical Power Subsystem (EPS): The EPS receives a maximum of 29 W from four deployable solar panels and boosts that voltage to charge the 38.5 Wh battery. Solar panels utilize AzurSpace photovoltaic cells, maximum power point-tracking and power conversion is implemented on the power manager, GOMspace's P31us, and the battery is GOMspace's BP4. Additionally, a DC-DC conversion board is used to generate 30 V and ±7 V bus voltages to power CITIES. The flight computer sends signals to the EPS to turn various subsystems on and off.

Thermal Control Subsystem (TCS): SOCRATES does not have an active thermal control system. Finite element thermal simulations have been performed to show that passive thermal management will keep the spacecraft systems within acceptable temperature ranges.

Structure (STR) Subsystem: The structure is fabricated mainly from Aluminum 6061. There are 3 distinct sub-structures: the detector housing protecting the satellite's main sensor; the board stack housing; and the solar panel assembly.

Propulsion Subsystem: SOCRATES does not have a propulsion system.

Payload Subsystem: The payload for SOCRATES is the Cesium Iodide Thallium-doped Incident Energy Spectrometer (CITIES). The CITIES detector system is a scintillator detector that uses cesium iodide crystals doped with thallium as the scintillators. CITIES has 14 channels of detection. CITIES aluminum 6061 main housing provides electromagnetic isolation. It uses signals emitted by x-ray pulsars to measure the range of a space vehicle relative to some predefined origin. It measures the arrival time of hard x-ray and gamma ray photons to 4 microsecond accuracy.