Measuring density during flight allows closed-loop control of maneuvering. Eliminating thrusters makes satellites much harder to track due to lack of emissions. Spacecraft need an alternative to thrusters to reduce fuel usage and costs.

What is PADDLES?
- PADDLES is a 3U CubeSat that will maneuver using only atmospheric drag instead of conventional thrusters.
- Developed at Rensselaer Polytechnic Institute, with parts from Pumpkin, Inc.
- The differential drag is created through the use of a repeatedly deployable/retractable drag sail (see other poster).
- PADDLES uses an atmospheric density sensor to predict when to open the sail and estimate the density on future orbits.

Mission Motivation and Goals
- Spacecraft need an alternative to thrusters to reduce fuel usage and costs.
- Eliminating thrusters makes satellites much harder to track due to lack of emissions.
- Measuring density during flight allows closed-loop control of maneuvering.
- A successful mission will use the drag sail to produce maneuvers using drag.
- Measuring the atmospheric density while in orbit is an additional success.

Key PADDLES Hardware
- Drag sail subsystem: The sail opens and closes to increase or decrease atmospheric drag.
- ADCS (Attitude Determination And Control System): Determines whether PADDLES is pointed in the correct direction and uses reaction wheels to control pointing. Different ADCS models can use either a star tracker or horizon sensors to determine the attitude while in orbit.
- EPS: Controls the distribution of power (collected by solar panels and stored in the battery) to all systems and boards.
- GPS: Provides location data for PADDLES while it is in flight. PADDLES contains an on-board algorithm to convert this into different frames.
- Motherboard and Processor: The CubeSat “brain.” The software necessary for operation is stored on this board.
- Radio: Used to relay information to the ground station on Earth, minimizing the processing power necessary in orbit.
- RAMS (RAM Sensor): A sensor used to measure atmospheric density. Under development by the Naval Research Lab (NRL), it will feed density information to the other systems on board PADDLES.
- Chassis: This is the “skeleton” of the satellite that keeps all hardware protected and in alignment.
- Drag Sail Control Board: Under development, will control the drag sail directly and monitor the open/close state.

What are CubeSats?
- CubeSats are small satellites intended for research and student missions. Most are about the size of a football.
- Each unit, denoted L, is 10x10x10cm, with a weight limit of 1.33 kg. CubeSats that are less than the full 3U can be stacked in the launcher to fill the 3U length.
- Most CubeSats are far cheaper than full-size satellites. A CubeSat can be on the order of $100,000 vs. $1,000,000 for a full-size satellite.

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