INTERPLANETARY CUBESAT NAVIGATIONAL CHALLENGES

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CubeSats are miniaturized spacecraft of small mass that comply with a form specification so they can be launched using standardized CubeSat deployers. The first CubeSat, an Earth orbiter, was launched in June of 2003, and since then many tens of CubeSats have been placed in orbit. CubeSats are often launched as secondary payloads and, up to now, have always been launched into Earth orbit. Placing a CubeSat into an interplanetary trajectory makes it even more challenging to pack the needed power, communications, and navigation capabilities into such a small spacecraft. Deep space communications require both a large ground antenna and a communications system in the spacecraft with sufficient receive and transmit gain and transmit power. The small size of CubeSats limits the size of the solar panels and also the size of the communication antennas.

Several interplanetary CubeSat mission are already in the development phase. NASA's Interplanetary Nano-Spacecraft Pathfinder in Relevant Environment (INSPIRE) has the goal to demonstrate the operation, communication, and navigation of CubeSats far from the Earth. There are proposals to fly CubeSats to the Moon, to near-Earth objects, and even to other planets and moons. These CubeSats will be using a miniaturized version of the transponder used by other deep space spacecraft that still have to perform all the necessary functions, but with a reduced mass and power consumption. Navigating interplanetary CubeSats presents a unique set of challenges because of the way the CubeSats are usually built and the limitations inherent with the small size of the spacecraft.

The power and energy limitations of CubeSats can make mission operations very different from those of bigger spacecraft. CubeSats may not be able to continuously transmit at the power levels required for interplanetary communication, and the length of tracking passes may be very limited due to energy and thermal constraints. The radio system in an interplanetary CubeSat is going to be a very substantial fraction of the mass and power of the spacecraft, and it may be difficult to operate it for long periods of time without it becoming overheated.

Reaching interplanetary targets is going to require adding a propulsion system to the CubeSat. As CubeSats are usually secondary payloads, they are not allowed to use pyrotechnics or hazardous materials, and limits are set on the pressure at which any fluids are kept and on the total chemical energy that they store. Waivers can be requested, but the operator of the primary payload is going to be reluctant to allow anything that may jeopardize or contaminate its own mission. This limits the kinds of propulsion systems that can be used and, consequently, the total velocity change that they can produce.

In addition, CubeSats are usually built using commercial off-the-shelf components and are assembled in environments that do not necessarily comply with stringent cleanliness requirements. If the CubeSat mission design requires it to come close to a protected solar system body, such as Mars or Europa, Planetary Protection rules may impose constraints into the way the mission is navigated, so as to reduce the probability of impact with the protected body.

The paper will describe the JPL interplanetary CubeSat mission concepts that are currently under development, and how they will be navigated, and will detail the approaches that are being taken to overcome the challenges foisted by the CubeSat paradigm.