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SAMUEL (Space Applied Mechanism for Unreeling ELectric conductive tethers)

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Abstract

The paper describes the hardware development of the unreeling mechanism for the ESAIL experiment at the example of the mission payload of the ESTCube-1 Pico satellite. Described here is a holistic approach of the whole deployment system with all its subcomponents and its verification concepts. For concept finding and definition, several tests were made to verify a robust tether deployment. There it has been shown that the complex process of deployment and retraction can be realized with a single motor drive.

1. Introduction

The Electric and Solar Wind Sail (ESAIL) is a new space propulsion system which allows using the solar wind as a natural resource for propulsion and delivers a controllable thrust over a long time period without fuel consumption. As a development step for a full scale mission, it is mandatory to proof the ESAIL principle in space environment. For deployment a single tether with limited length in space, a Picosat mission, realized with ESTCube-1 is a very capable way to demonstrate its working principle with limited resources.

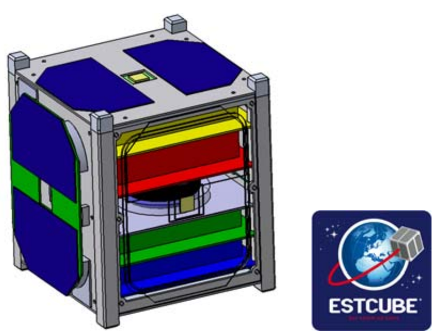

Figure 1: ESTCube-1 Picosat

2. Deployment system principles

The task was to develop a deployment system that allows having a reliable deployment of the tether under any given circumstances. This is a key technology for the whole ESAIL principle and a premiere of the deployment of an ultra-thin micrometeoroid tolerant tether in space.

2.1 Retractable

The retractable version is far developed. Hereby the deployment of the tether out of the satellite is just provided by the centrifugal force and the motor is just needed to provide a steady and controlled deployment speed as well as to stop the tether from unreeling during spin-on sequences. These sequences are mandatory to provide a minimum of centrifugal force for deployment, to avoid the tether to get stuck inside the satellite or to reel up again in the opposite direction. Due to the low power generation of the Cubesat, a stop period might be mandatory as well to re-load the batteries for motor driving. In combination with a “one way deployment device”, it might be possible as well to use the motor in case of cold welding to liberate the tether and reduce the jamming risk.

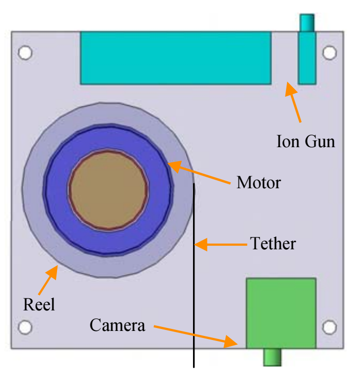

Figure 2: Retractable deployment system

2.2 Non-retractable

The non-retractable one shot device is more reliable in deployment, due to the tether release right at the satellite wall. This is made with a motor driven capstan, which pulls out the tether from the reel. The drawback hereby is that the capstan is squeezing the tether between its rollers, so the pulling itself may break the tether or its loops. This might occur as well, as the tether can rupture and lose its connection to the high voltage source. So the higher reliability in deployment is bought against a lower robustness of the mission itself.

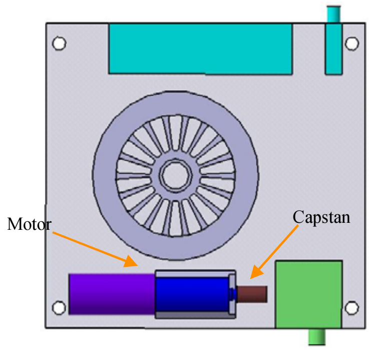

Figure 3: Non-retractable deployment system

3. Testing and test results

3.1 Deployment verification unit

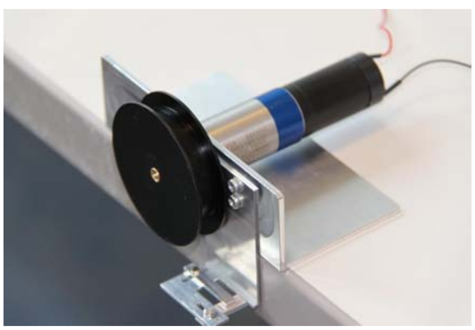

Figure 4: Deployment verification Unit

To find the optimal positioning of the reel inside the payload compartment of ESTCube-1, a test unit was developed with adjustable distance and size of the satellite tether exit. Several tests were made to verify the minimum and maximum spin rate of the satellite to find an operation window under which a reliable tether deployment can be estimated.

3.2 Challenges

Cold welding

This might become a problem, currently it is figured out if a coating might be possible without changing the wire performance and increasing the weight too much. In addition, a fail safe mechanism needs to be developed for the case that a partly cold welded tether would rewind the tether accidently by keeping the rotation direction and pulling the tether back inside the satellite. This problem can be handled with a one way “valve” system, which keeps the tether from being rewind.

Tether jam

The current tether design shows some points of weakness due to the ultra thin wire and its mechanical stress during winding / unwinding of the tether. It occurs that the wire loops get broken easily and those loose wires could create short circuits inside the satellite or create a jam when parts of the broken loop get stuck inside the satellite and avoid unreeling.

Short circuits

To avoid the high voltage loaded tether from getting in contact with any conductive part inside the satellite, an insulation system is under development that capsules the tether from the rest of the satellite.

4. State of the Art

Currently at DLR Bremen, there is an “engineering qualification model” under development, which will be used for testing and verification under space environmental circumstances. Different tests can be made to verify the calculations and estimations made during development as well as to search for weak points in the design of the deployment system.

5. Further applications

With a successful demonstration mission with a tether deployed by ESTCube-1, the next step is to leave earths influence and shielding against solar wind and head to deep space to verify the technology for deep space exploration missions. After this technology established as an alternative propulsion system for exploration of the solar system, a full science mission to the rim area and the asteroid belt could be realized in a much faster, cheaper and due to its lack of propellant, with an pretty high Payload to structural mass ratio as with conventional propulsion systems.

An additional application is to use the tether deployment mechanism for Pico- and Nano-satellites for controlled de-orbiting and space debris avoidance policy. Therefore, the tether could be used as a plasma brake to slow down or speed up the satellite in interaction with the magnetic field of the earth.

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