ESAIL D32.3
Main tether reel test plan

Work Package: **WP 32**

Version: **Version 1.0**

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Date: Helsinki, November 6th, 2013

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1. Purpose

The purpose of this document is to present a test plan for the tether deployment system on the Aalto-1 satellite containing 100m of 4-wire hey tether.
In this document the tether reel is the actual reel that the tether was manufactured on. In addition the deployment system consists of isolation for the tether, two launch locks, an unreeling motor, and an end mass to extract the tether in space.
While the unreeling procedure described here closely resembles the one conducted at DLR for D31.3, there are notable differences; (1) the tether type (4-wire vs. 2-wire Heytether), (2) the tether length (100 m vs. 11m), and (3) the layered structure of the tether on this reel. In addition, one tether reel will undergo a vibration simulation before the unreeling. The bond quality on the tether is also investigated after unreeling.

2. Introduction

The Electric Solar Wind Sail (E-sail) is a proposed propellantless propulsion method for interplanetary missions.
It uses centrifugally stretched positively charged tethers to create thrust from the momentum flux of the solar wind. The magnitude of the theoretically estimated E-sail effect should be experimentally verified in space.
The tether is stored on a reel [1] [2] during the spacecraft launch. It is manufactured by the Tether Factory [3] (D21.3) directly onto the reel that is used on the mission. Once in orbit, the tether is unreeled. Reliable tether deployment is a requirement for successful E-sail missions.

3. Test overview

The aim of the tests is to investigate the tether unreeling, to verify the reliability of the unreeling procedure and to ensure that the bonds do not suffer from stacking many layers of tether or by the unreeling procedure. All tethers will be used only once (reel out only), and samples will be extracted from the unreeled tether. The tests will be videoed to allow close *post hoc* visual inspection. A vibration simulation will be done on a LDS v650 vibration bench at the University of Tartu. The vibration simulates the launch vibrations of a European Space Agency Vega booster rocket [4]. Two unreeling tests will be done: before and after the vibration. Both test sequences will be performed in the same manner.

3.1 Tether description

The tether is a 4-wire Heytether comprising of dia=50 μm base wire and three dia=25 μm loop wires. The loops are 3.5 mm tall and their length is 20 mm on one loop wire and 40 mm on the other two.
The tether is manufactured onto its mission reel to minimize the risk of breaking the tethers integrity during transfer from reel to reel. In addition, during manufacture, the tether is reeled so that the tether build-up on the reel is even, Fig 1.

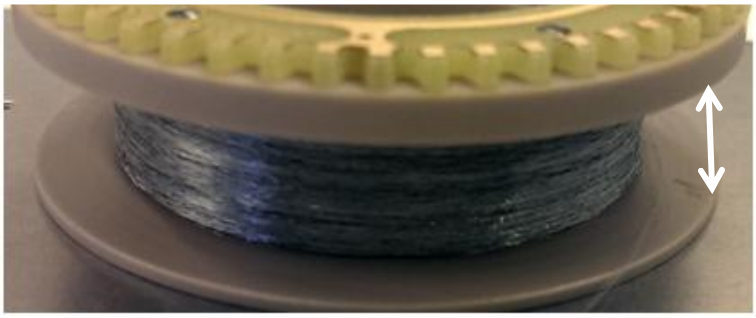

Fig 1. 100 m of 4-wire Heytether on an Aalto-1 flight reel. There are 15 layers of tether on the reel. The tether is uniformly distributed over the available space (1 cm, indicated by an arrow).

3.2 Deployability

The deployability of tether will be tested by unreeling tethers by gravity. The tethers are unreeled in the HU Physicum building in a 15 m tall staircase. Various suitable end masses are used to find the minimum mass for successful unreeling (The end mass of the flight model will weight 1 – 1.2 g). The end mass is reattached near the spool at every 15 m. The test is performed before and after the tether suffers through the vibration simulation. The tests are done with and without the reel isolation to determine whether the isolation has affects the deployability of the tether, Fig 2. Both tests are done using similar unreeling speeds that correlate with those used when unreeling the tether in space (1–3 mm/s) [5]. A Maxon 24V Maxon DC 2332.968-21.216-200 motor is used for the unreeling.

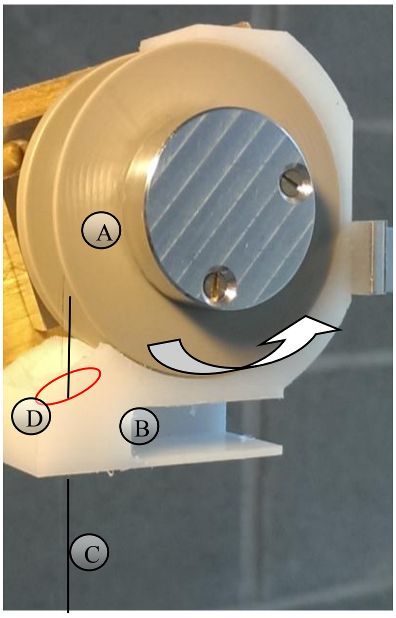

Fig 2. A) Tether reel, B) Tether isolation (cut open to enable visual inspection of tether behavior during unreeling), C) Tether (enhanced for visibility), D) Opening in the isolation for an end mass and tether outlet.
To outreel the tether, the reel is turned in the direction indicated by the arrow. If the tether gets stuck on the reel, it is pressed against the inner wall of the tether outlet (indicated by a red circle).

3.3 Effect of unreeling on bond quality

As a standard procedure, the quality of the bonds on the tether is verified before and after production by destructive pull testing [3]. This assures that there is no significant drop in the maximum sustainable pull force of the bonds during production.

Similar pull tests are done on the bonds of unreeled tethers. The sampling scheme is presented in Fig 3.

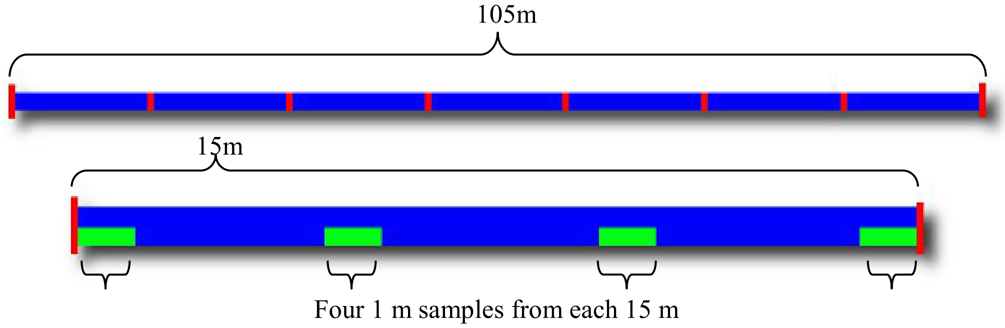

Fig 3. Sampling scheme for the pull tests.

3.4 Deployment system

The deployment system is similar to that used in the ESTCube-1 [1] [2], Fig 4. The deployment system is put to the same vibration test bench as the reel holding the tether. All systems are tested after the vibration.

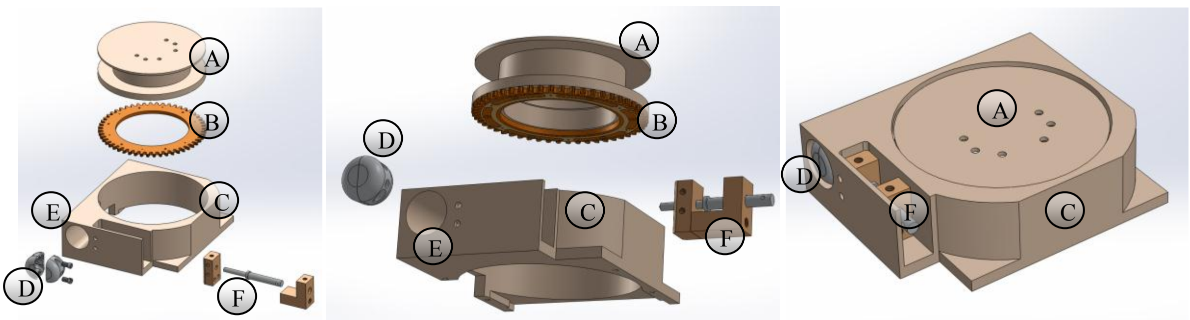

Fig 4. CAD-drawing of the deployment system. A) Tether reel, B) Slip ring and electrical contact, C) Tether isolation, D) End mass E) End mass opening, F) Launch lock for the end mass. (Additional lock will be added to lock the reel in place during the launch, not pictured)

4 Success criteria

The experiment is successful if both tethers (before and after vibration) are unreeled using an end mass of less than 0.25 g. This leaves a safety margin of 0.8 – 1 g to the planed end mass weight of 1 – 1.2g of the Aalto-1 plasma brake payload.

References

[1] Krömer, O., et al. *SAMUEL (Space Applied Mechanism for Unreeling ELectric conductive tethers).* European Planetary Science Congress 2010. Vol. 1. 2010.

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[3] Henri Seppänen, Timo Rauhala, Sergiy Kiprich, Jukka Ukkonen, Martin Simonsson, Risto Kurppa, Pekka Janhunen, and Edward Hæggström. *One kilometer (1 km) electric solar wind sail tether produced automatically.* Review of Scientific Instruments 84, no. 9 (2013): 095102.

[4] Arianespace, *Vega User's Manual*, http://www.arianespace.com/launch-services-vega/VEGAUsersManual.pdf, November 2013

[5] Kestilä, A., T. Tikka, P. Peitso, J. Rantanen, A. Näsilä, K. Nordling, H. Saari, R. Vainio, P. Janhunen, and J. Praks. *Aalto-1 Nanosatellite-technical Description and Mission Objectives*. Geoscientific Instrumentation, Methods and Data Systems 2 (2013): 121–130.