



# ESAIL D21.2

## Tether factory (1 km) requirements

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### 1. Purpose

The purpose of this document is a) to list what the tether factory should do and what specifications it needs to fill, b) to list specifications of the parts that comprise the factory as well as the raw material from which the tether is built.

### 2. Introduction

The Electric Solar Wind Sail (E-sail) uses centrifugally stretched positively charged tethers to create thrust from the momentum flux of the solar wind. A full-scale E-sail should produce one Newton of thrust from one hundred 20 km long tethers. Other configurations featuring 2000 km total tether length are also possible.

For micrometeoroid resistivity, multifilament tethers are needed. In addition, the tethers must be electrically conductive, thin and strong enough to sustain the centrifugal force generated by the rotating E-sail.

The electric conductivity, density, and tensile strength of the Al(Si1%) bonding wire meet the requirements of the E-sail tethers. Al-Al bonds are known to be reliable in long term use.

In this deliverable we present the requirements for a tether factory capable of producing 1 km of E-sail tether out of Al wire 25-50  $\mu\text{m}$  in diameter.

### 3. Requirements for 1km Tether Factory

#### 3.1 Tether requirements

The tether must be conductive and micrometeoroid resistive. It needs to sustain the centrifugal force (50 mN) of the full scale E-sail. Tolerance for micrometeoroids is achieved by multifilament 4-wire tether where the redundant loop wires are not stretched together if the base wire is cut by a micrometeoroid. The key requirements

of the tether are listed in table I.

**Table I**

Tether conductivity	NA
Force tether needs to sustain	50 mN
Number of wires	4
Variation in loop length	5 mm

### 3.2 Requirements for the tether material

Based on the previous knowledge from the 100 m tether production the specific requirements for the tether material and design are listed in table II. These requirements are based on the 4-wire hey tether design where multiple loop wires are bonded on one base wire. These requirements are based on Al(1%Si) bonding wire material.

**Table II**

Tether length	1 km
Base wire diameter	50 $\mu\text{m}$
Loop wire diameter	25 $\mu\text{m}$
Number of loop wires	3
Distance between single bonds	10 mm
Loop length	30 mm
Loop height	5 - 30 mm

### 3.3 Tether factory requirements

The tether factory (TF) produces conductive and micrometeoroid resistive tether that fulfils the tether requirements. The tether is produced on a spool so that it can be reeled out in space. Table III lists the requirements for the tether factory. The standard wire spools and bonding machine in the production laboratory (Department of Physics, University of Helsinki) are listed as requirements but may be changed if the production facilities change.

**Table III**

Task of the TF	1 km tether production that fulfil the tether requirements
Base wire	1.1 km Al(1%Si) 50 $\mu\text{m}$ wire on 50 mm spool
Loop wires	2.0 km Al(1%Si) 25 $\mu\text{m}$ wire on 50 mm spool
Bonding machine	K&S – 4123 ultrasonic wire bonder
Precision in wire alignment	5 $\mu\text{m}$
Repeatability	100 000 bonds