3rd Nanosatellite Symposium
Kitakyushu, Japan
12-13 December 2011

A Mechanical De-Orbiting System for a 3 Unit CubeSat

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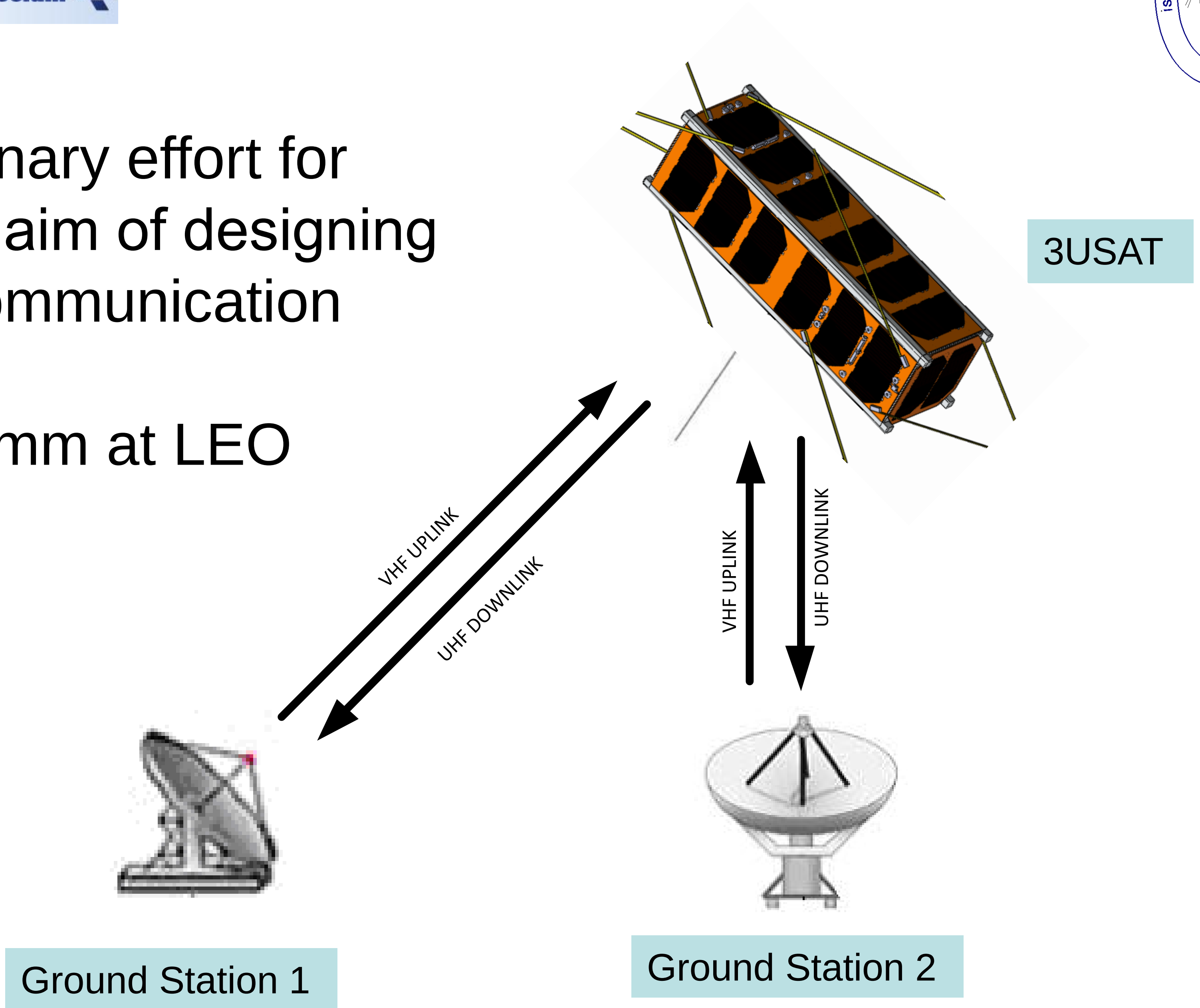
TURKSAT 3USAT MAIN MISSION

A preliminary effort for Turkey’s aim of designing native communication satellites

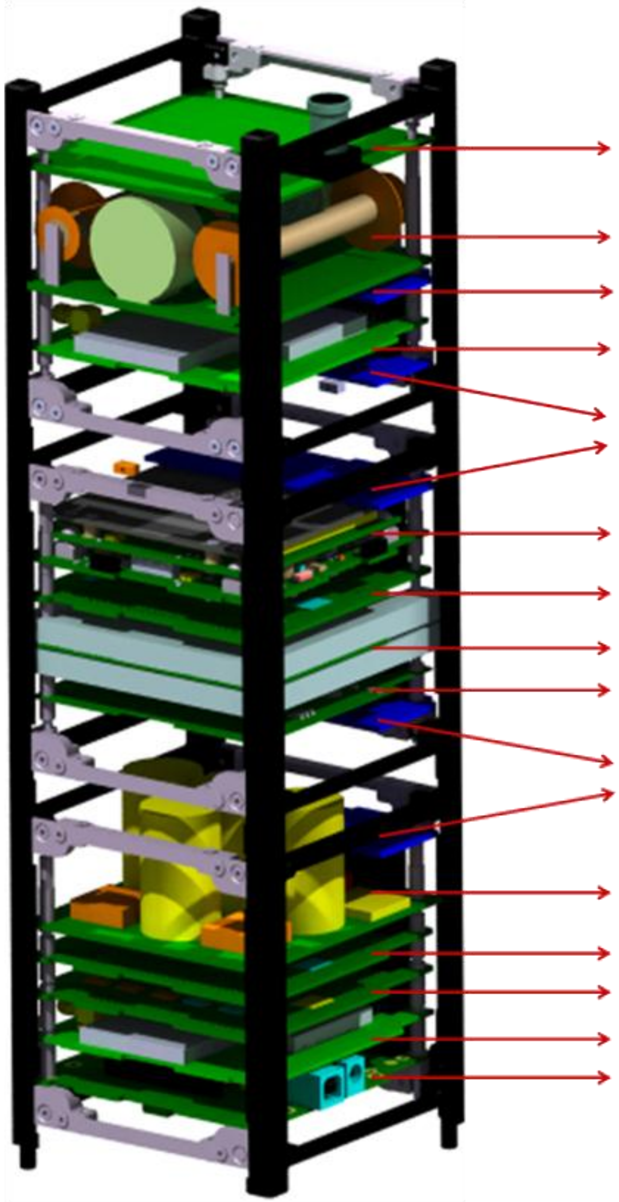
Voice comm at LEO

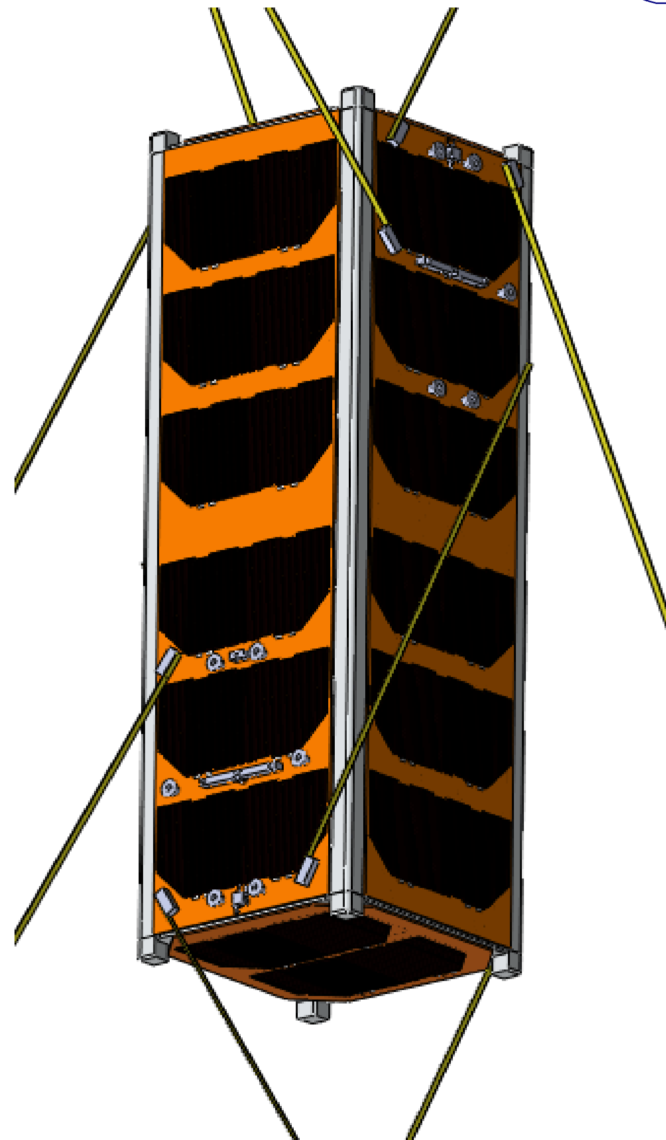


3USAT Project Overview

- Voice communication at low earth orbit
- Education
- Redundancy
  - COTS systems and in-house development
- Passive AC system with hysteresis rods
- De-orbiting system (DOS)
- Low cost technology test bed
- CDR Phase
- Launch: 2012

SUBSYSTEMS


Camera / Beacon II
DOS
Modem
1U Interface
EPS I
Transponder II
PMACS
OBC
1U Interface
EPS II
Transponder I
Modem I
ADCS/Beacon I
Main OBC



MASS BUDGET

MASS BUDGET	
SUBSYSTEM	**MASS (gr)**
Structure	580
Thermal	150
Stabilization	250
Mechanisms	225
EPS	1000
Transponders	500
OBC	250
De-Orbiting Subsystem	330
Modems, beacons, antenna	435
Camera	80
Margine	200
Total	**4000**

Space Debris Issue

- Increasing small satellite population in low Earth orbit
- Conjunctions, Collisions, Kessler Syndrome.

	Debris Size		
	1mm to 1cm	1cm to 10cm	More than 10 cm
LEO debris	16 million	270.000	14.000
Total debris at all altitudes	150 million	650.000	22.000

UN Regulation on DOS

- Satellites at low Earth orbit have to de-orbit within 25 years after their end of life

- In line with UN regulation: a mechanical de-orbiting system is proposed to de-orbit 3USAT within 20 years from an altitude of 680 km.

TRADE STUDY

DOS for a 3 Unit CubeSat orbiting at 680 km

- Small volume,
- Low weight,
- Low energy consumption,
- High space resistance,
- High reliability,
- Ease of manufacturability, and
- Low cost,

Four types of systems ➔ mechanically deploying membranes

TRADE STUDY

	Deployable Membranes	Micro PPT	Cold Gas Thrust	Terminator Tether Tape
Small Volume	8	6	1	8
Low Weight	9	4	2	3
Space Resistance	9	9	9	9
Low Cost	5	2	1	5
Low Energy Consumption	8	1	7	8
Reliability	4	4	4	4
Ease of Production	7	4	4	8
TOTAL	50	30	28	45

Working Principle

- To de-orbit within 25 years by increasing the drag force exerted on 3USAT by enlarging the frontal surface area deploying membranes.
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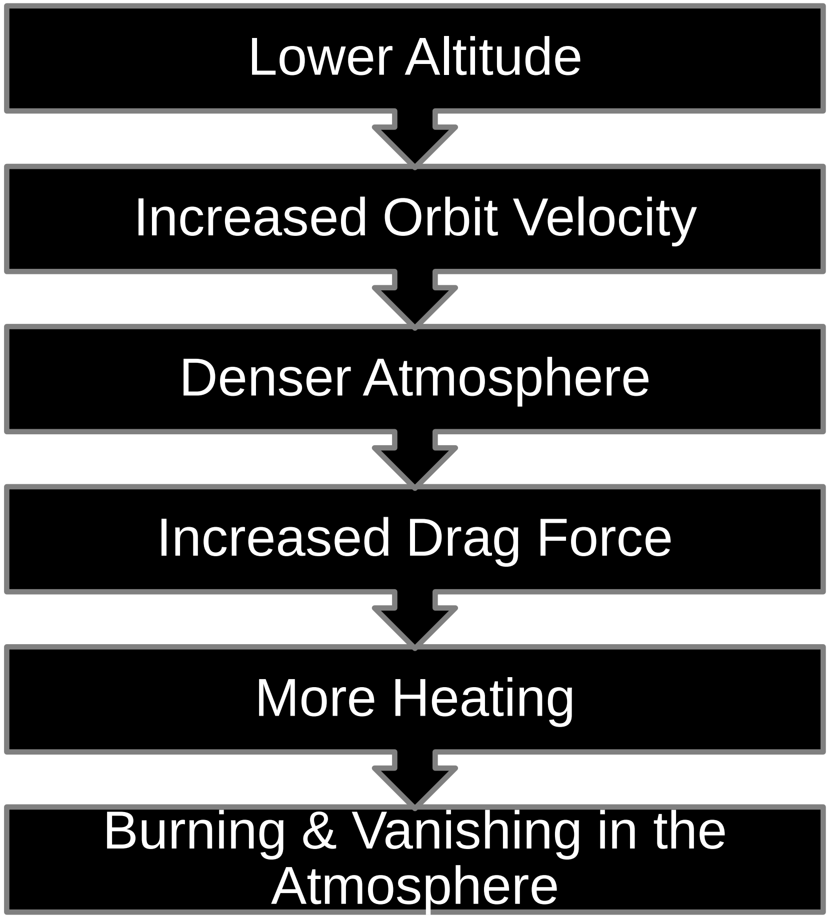
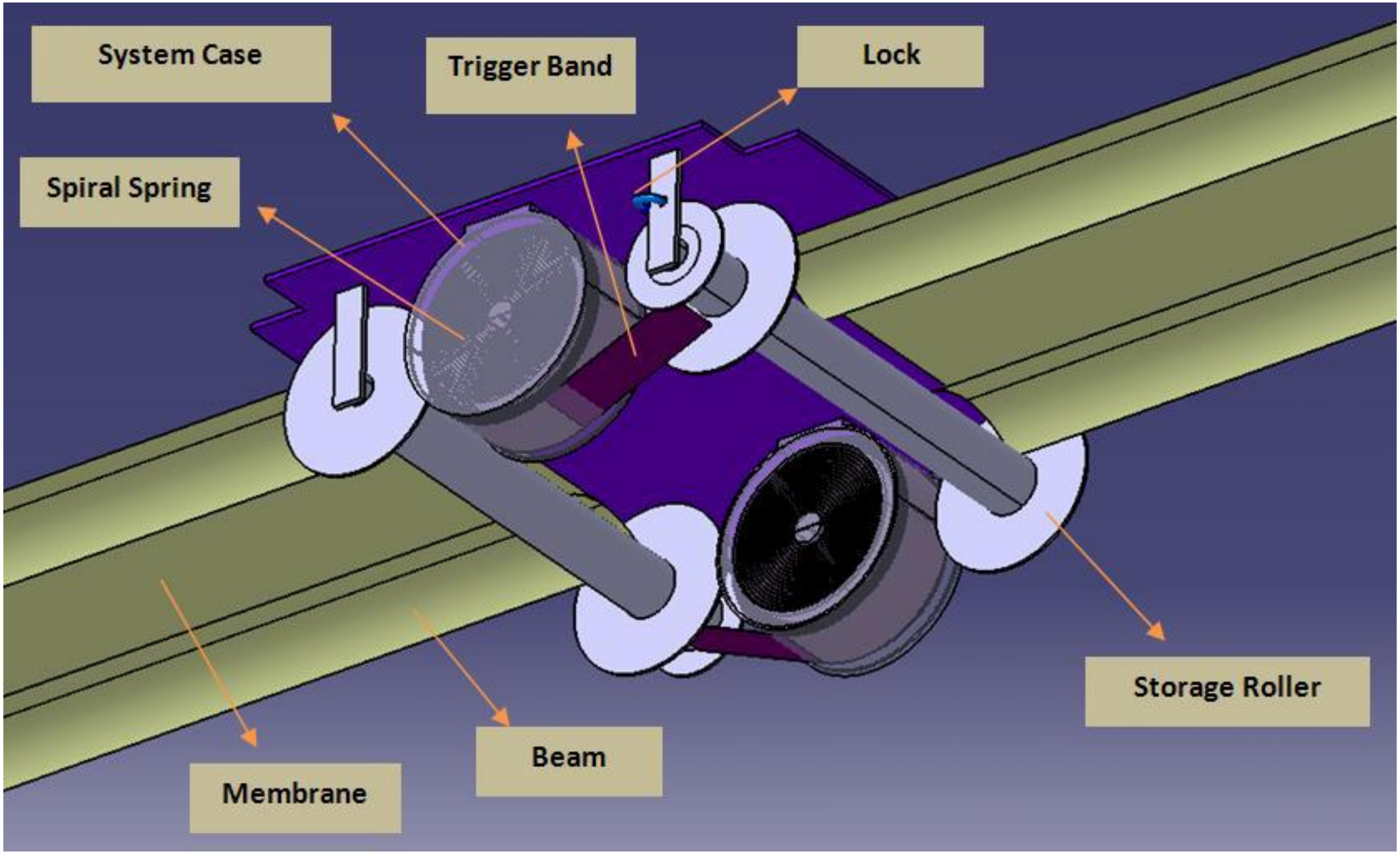
- After completion of the satellite’s mission 2 membranes supported by band beams will be deployed mechanically against each other. The area of the deployed membranes determines the de-orbiting time



De-orbiting System



DOS Elements

- **1. Membrane – Beam Couple:** Main duty of the membrane – beam couple is to de-orbit the satellite by increasing the frontal surface area. Kapton HN is selected as membrane material since it has low density (1.42 gr/cm^3) and material properties are almost constant in a wide temperature range (-269 ^oC to +400 ^oC).
- De-orbiting system will carry 2 membrane – beam couples to be deployed in opposite sides.

- **2. Storing Unit:** Consisting of 2 storage rollers, storing unit used for storing the membrane – beam couple while the de-orbiting system is de-active.
- To be produced from Al-7075 due to resistant to space environment.

DOS Elements

- **3. Spiral Springs, Storing Cases and Bands:** The system consists of 2 spiral springs, their cases and 2 bands. Spiral springs store the required energy for deploying the membrane – beam couple. Bands transmit the required deployment energy from springs to the storage cylinders. Storing cases conserve the spring - band system and assists the storage of the bands.

- **4. Locks:** prevent the deployment of the system while 3USAT is operational. Lock mechanism consist of a thin rope called “Dyneemo Wire” and a Nichrome wire to cut the rope by passing current on it. Two locks are located on the system.

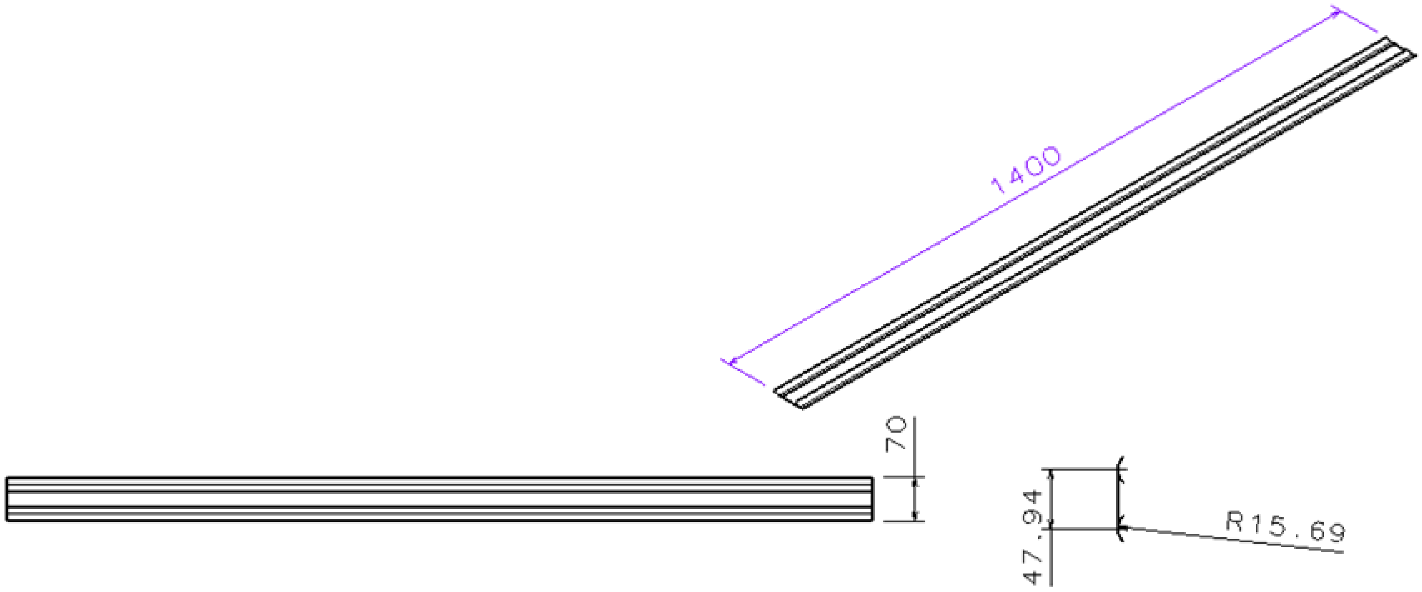
Membrane Sizing

- The required membrane area is calculated considering satellite lifetime analysis with STK (Satellite Tool Kit) Program.
- The most pessimistic atmospheric density model is selected in order to prevent de-orbiting delays. *According to the Harris-Priester atmospheric model, 0.2 m^2 membrane area is required in order to de-orbit the satellite from its orbit in 19.7 years. This area is provided by deploying 70 mm wide and 1.4 m long two different membranes in opposite directions.*

- Membranes have to be supported by light beams for protection against large deformations.
- NASTRAN FEM analysis to size the beams.

Membrane-beam couple

- Curved Steel Tapes having a thickness of 0.15 mm and Kapton HN film having thickness of 0.120 mm is chosen to construct the membrane-beam couple.

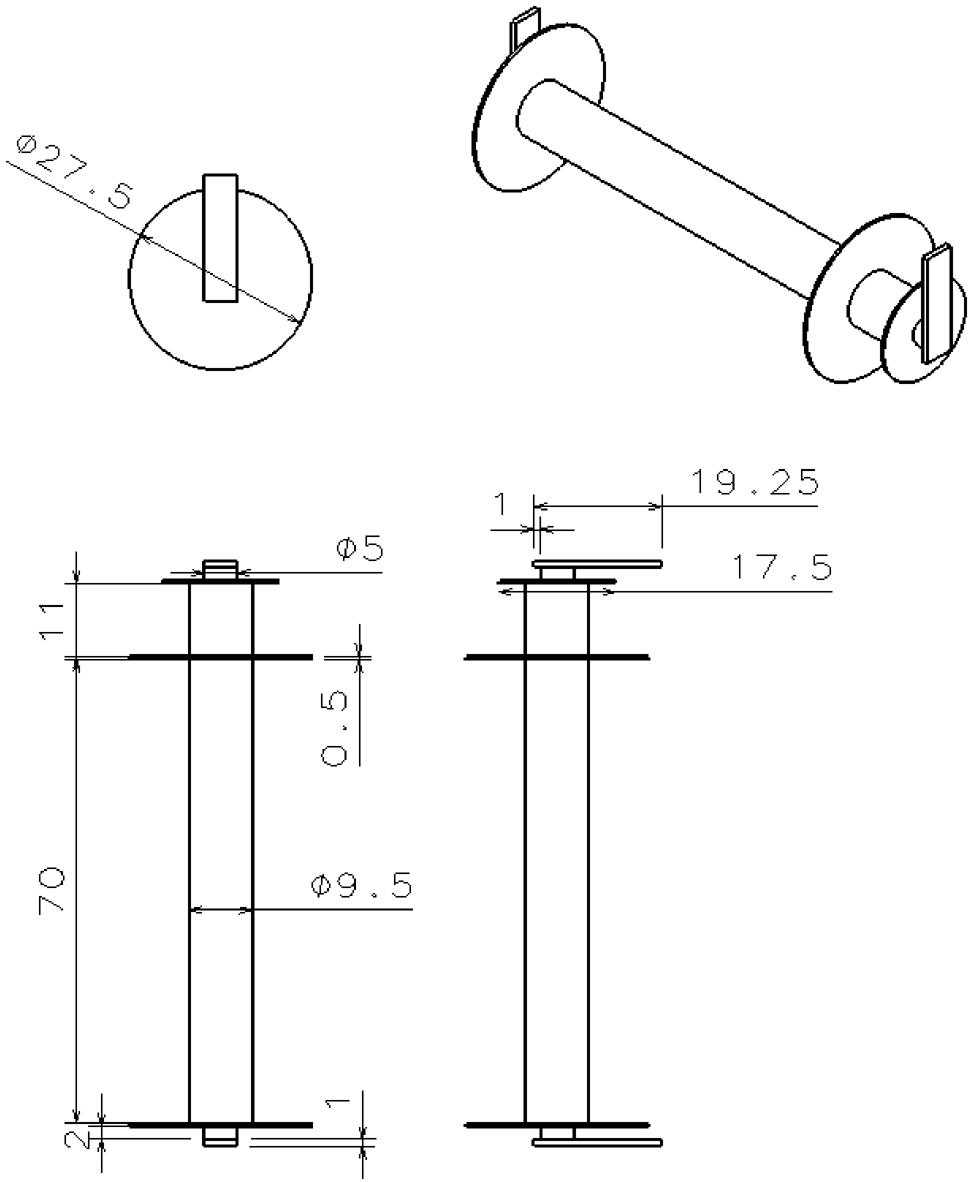


Storage Rollers

- Storage rollers should store the membrane-beam couple as in a small volume as possible, a Matlab code is written in order to determine the most suitable cylinder diameter.

- The thinnest storage roller is found to have a diameter of 9 mm (curved steel rolers).
- 9.5mm is selected.

Storage Rollers



Spiral Spring Calculations

2 spiral springs each to store the required energy for driving the storage rollers:

$$M = \frac{\pi E b t^3 \theta}{6L} \qquad S = \frac{6M}{bt^2}$$

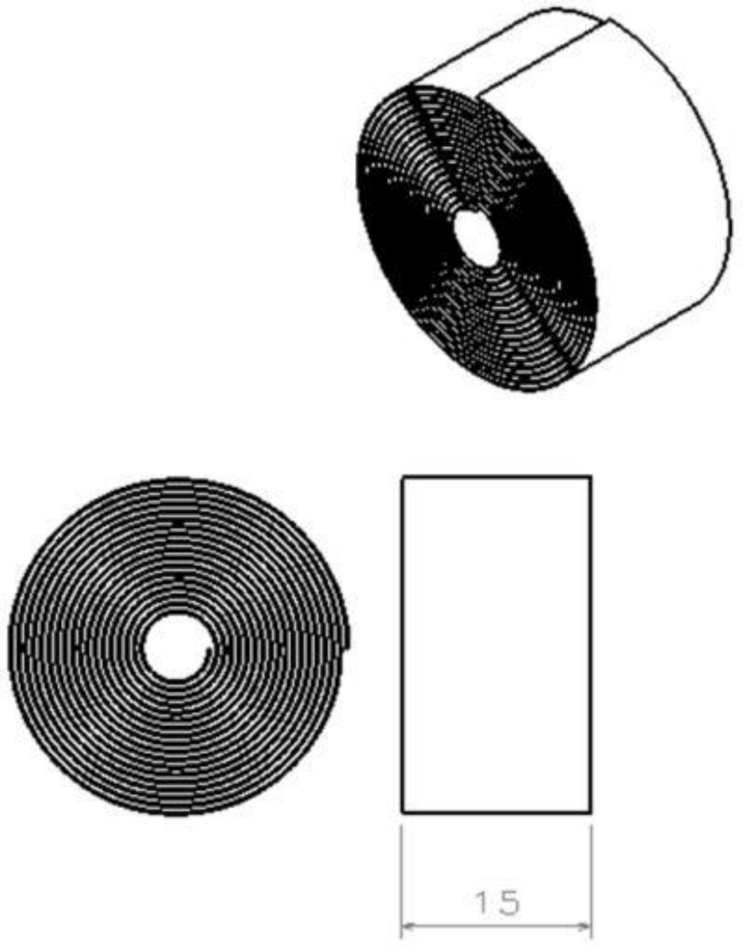
M: Torque produced by the spring (N.mm)
S: The stress exerted on the spring when it is compressed (MPa)

E: Elasticity modulus of the material (MPa)
Θ: The number of spins when the spring is compressed
L: Active spring length (mm)
b: Width of the spring (mm)
t: Thickness of the spring (mm)

Spiral Springs

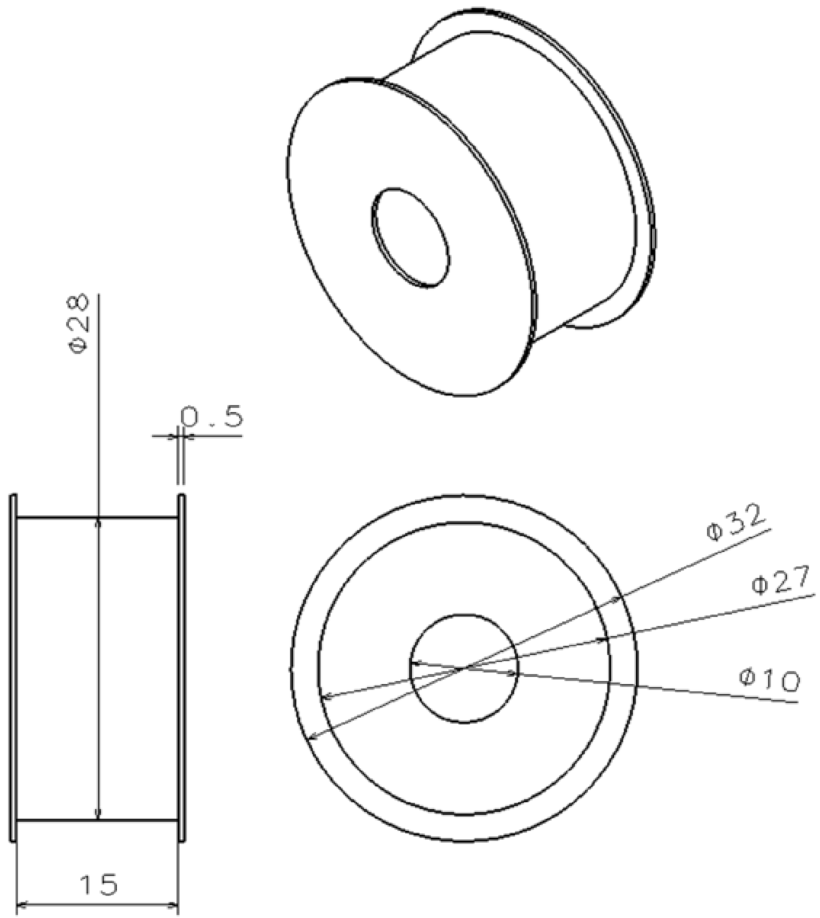
Input	
S [10]	1620 MPa
t	0.15 mm
b	15 mm
E	207 GPa
Membrane length	1300 mm
$D_{iç}$	5 mm
$D_{dış}$	27 mm

Output	
θ	**15,326**
M	**91.125 N.mm**
L	**922.84 mm**



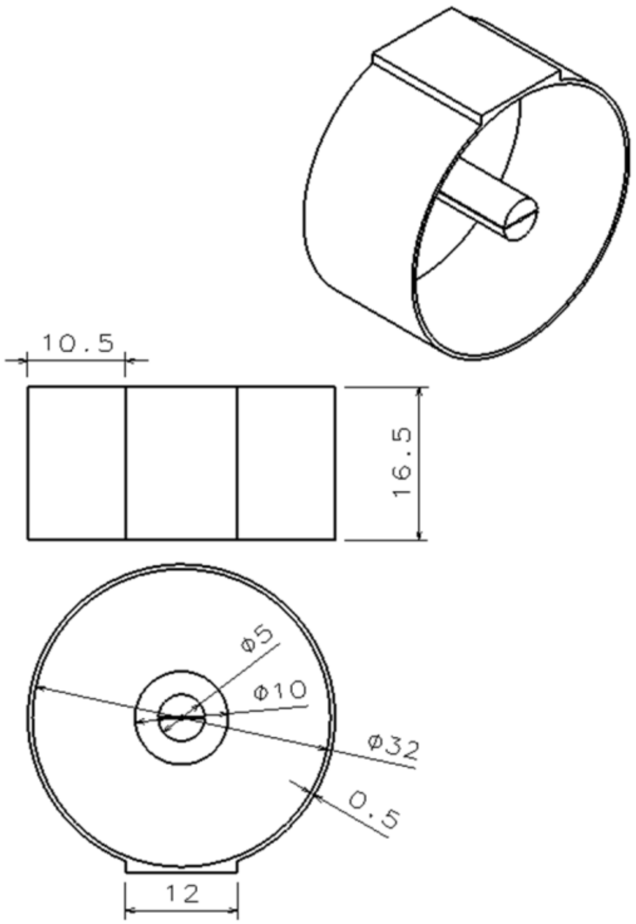
Sizing of the Cases

A spiral spring case which will be the nest of the spiral spring and trigger band is sized based on the spiral spring's dimensions.

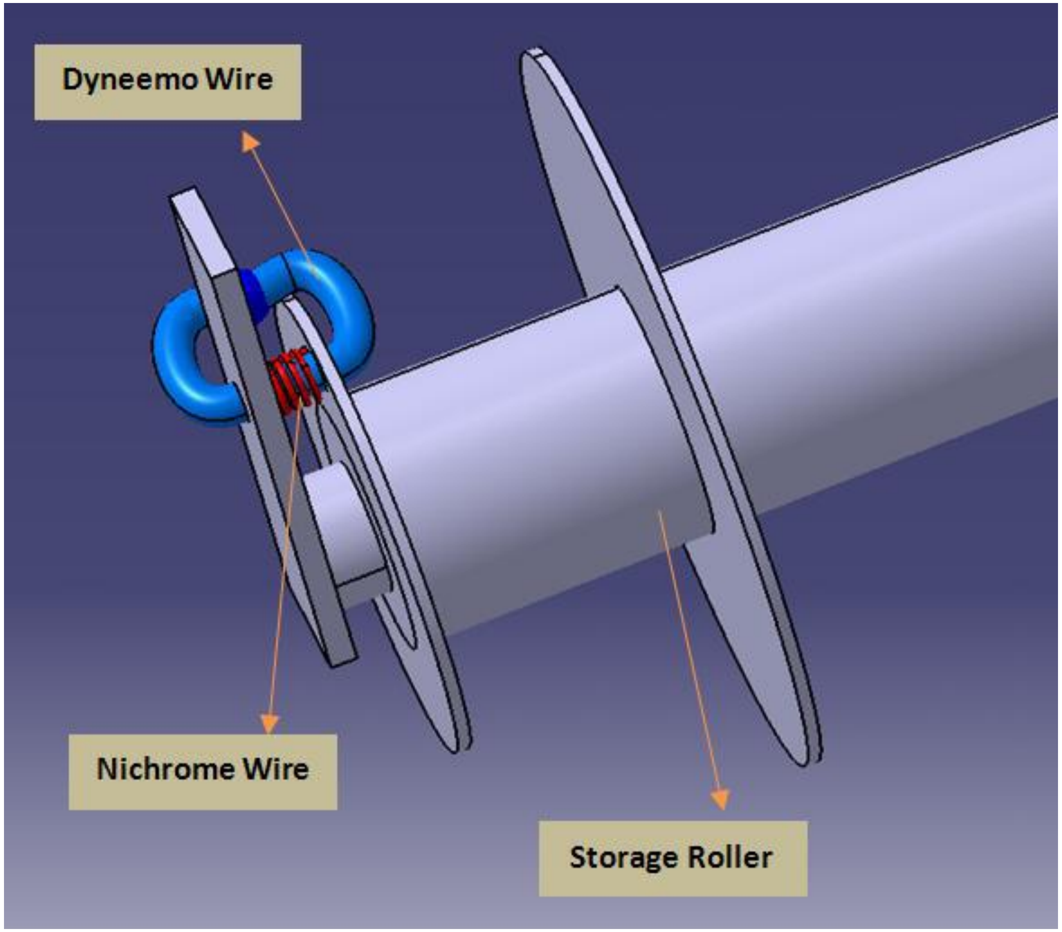


System Case

- to fix the spiral spring's inner tip to its center and to let the wrapping of the trigger band on the spiral spring case via the rotation movement like in the steel tape measures.



Locking Mechanism



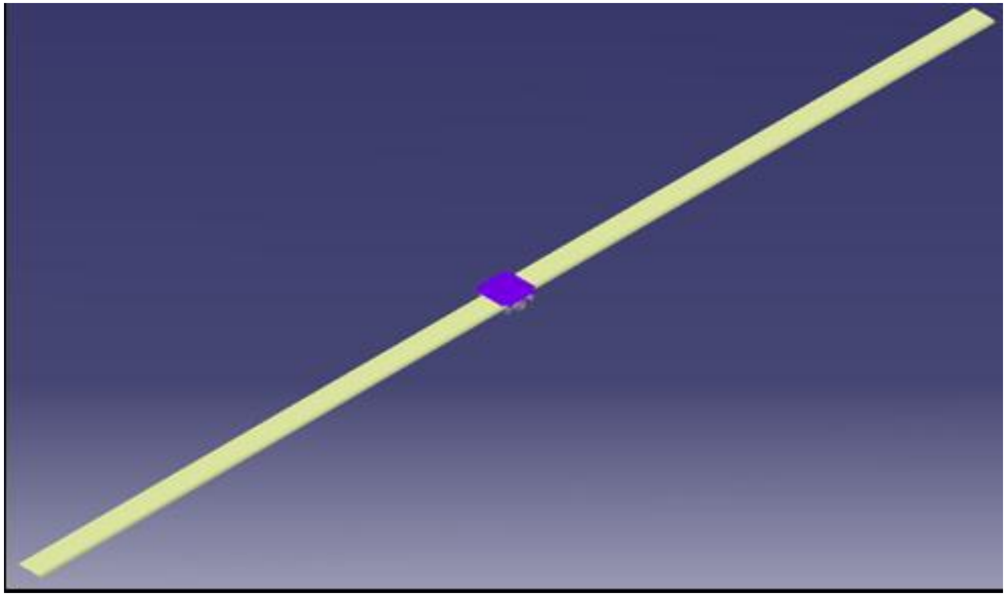
Power and Mass Budget

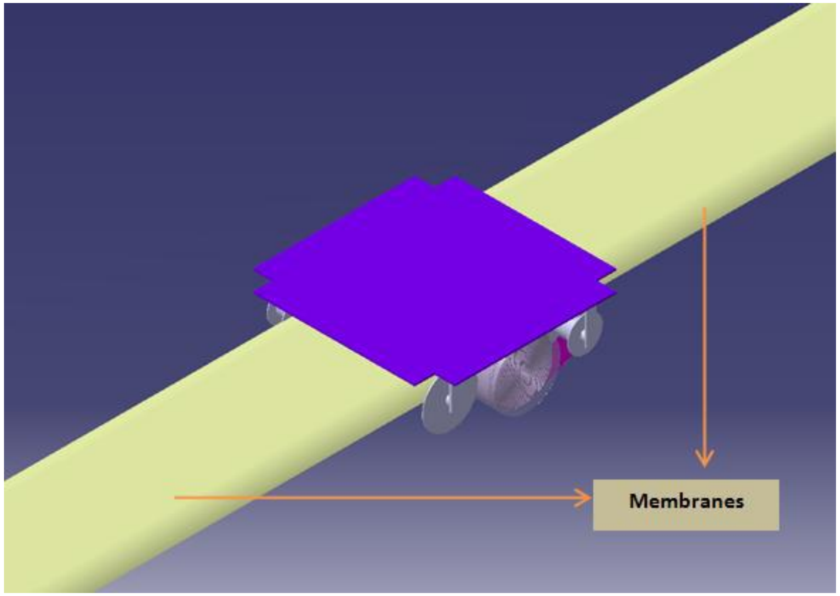
Element	Mass
Membrane-beam (2)	190
Cylinders (2)	36
Spiral spring (2)	32
System Case (2)	10
Spring Case (2)	6
Kapton Tape (2)	6
Lock (2)	30
Connectors	20
TOTAL	**330gr**

State	Power (Watt)
IDLE	0
OPENING (Max)	2

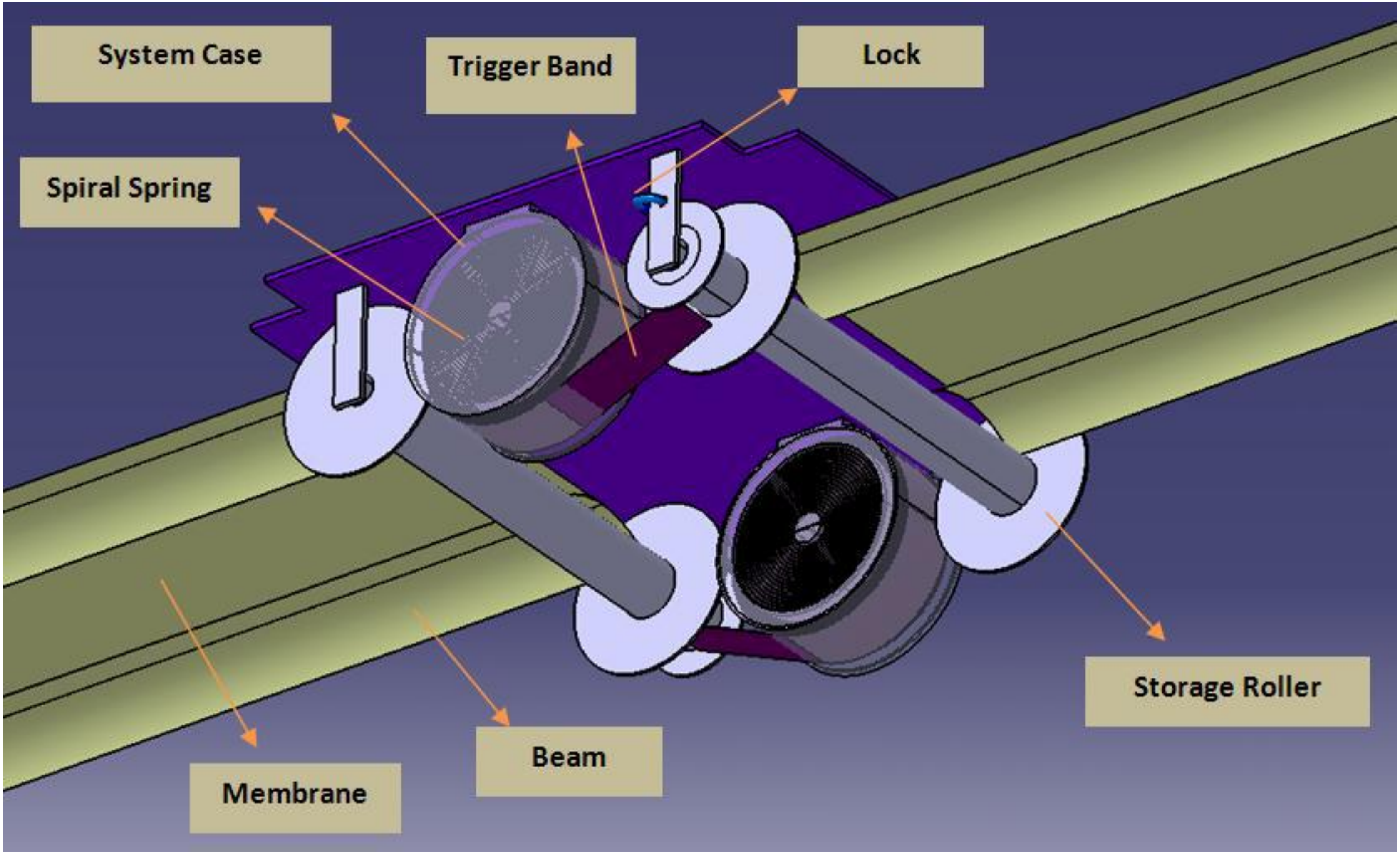
For cutting the Dyneemo Wire (locking rope) to deploy the membrane-beam couple.

De-orbiting System





De-orbiting System



Future Work

- Materials are acquired
- Manufacturing of the EM and FM
- Deployment tests
- Environmental tests using available in house equipment


Thank You!