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clean space industrial days

e-Deorbit: Flexible Session

DESIGN AND DYNAMIC TESTING OF TETHER SYSTEM AS ACTIVE CAPTURE TECHNOLOGY FOR E.DEORBIT AND NET/HARPOON-BASED MISSIONS

Authors:
Lorenzo Marconi, Arescosmo
Andrea Messidoro, Arescosmo
Alessandro Chiesa, Aviospace
Giovanni Gambacciani, Aviospace
Luigi Maffioli, Gottifredi Maffioli
Kjetil Wormes, ESA-ESTEC
Sarmad Aziz, ESA-ESTEC

Speaker: Lorenzo Marconi
Email: marconi@arescosmo.it

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COMPANY PROFILE

From the split between the AIRBORNE and DEFENCE & SPACE divisions within AERO SEKUR SpA, as of May 2017 two companies were created:

ARESCOSMO SPA DEFENCE AND SPACE

PRODUCTS FOR DEFENCE & SPACE INDUSTRY

AEROSEKUR

PRODUCTS AND SERVICES FOR HELICOPTER INDUSTRY

LOCATIONS

Torino

Space Division
Advanced Engineering Unit

Arenzano

ARESISTEMI

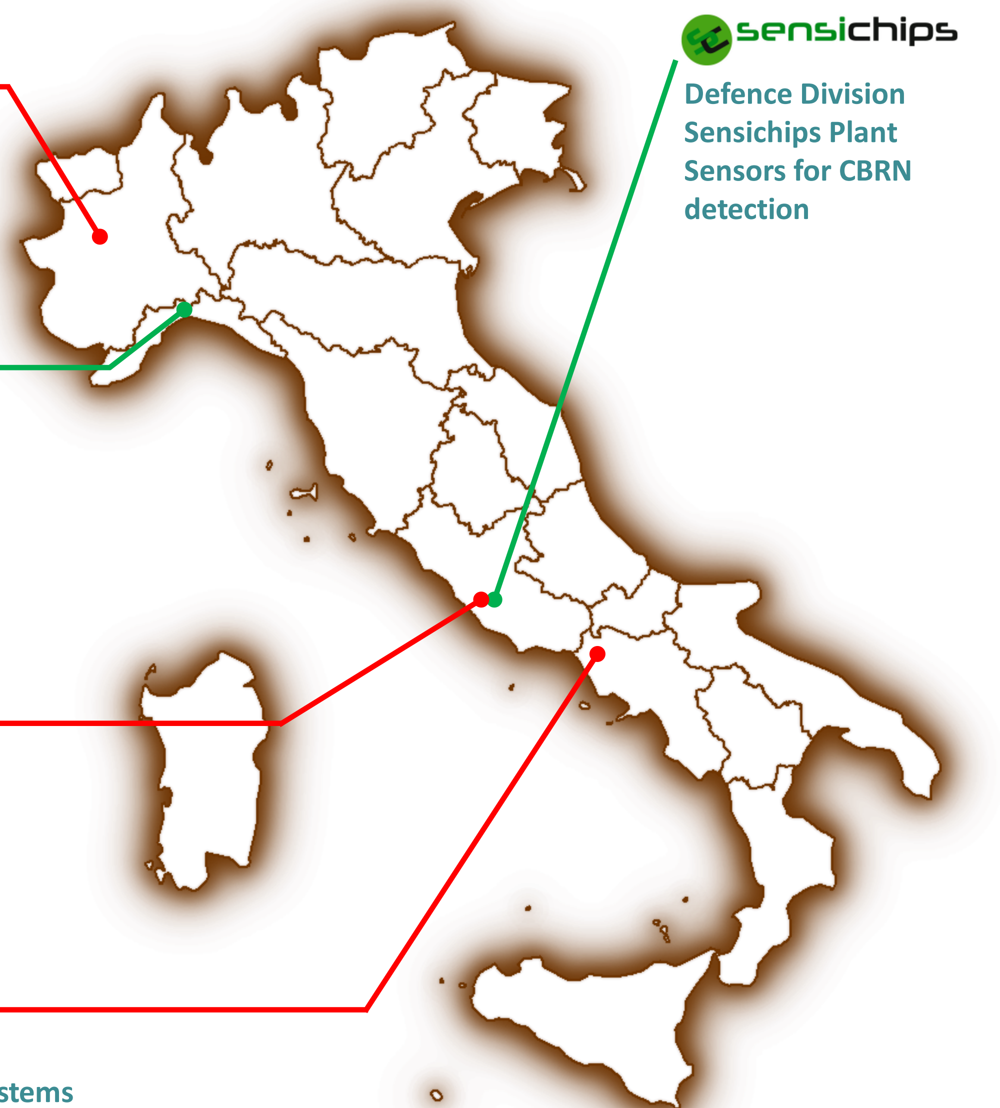
Defence Division
Aresistemi Facility

Aprilia

Defence and Space Division
Main Headquarter & Facility

San Pietro Infine

Defence Division
F35-JSF Program - Inflatable Shelter Systems



sensichips

Defence Division
Sensichips Plant
Sensors for CBRN detection

PRODUCTS PORTFOLIO

DEFENCE

- CBRN Protection Mask
- CBRN Filter
- CBRN Permeable Suit
- "First Aid" CBRN Poncho
- Ballistic Jacket
- Ground Support Equipment
- Airdrop Systems
- Parachutes
- HVAC Systems

SPACE

- Planetary Re-entry Descent & Landing Systems
- Inflatable Habitat Modules
- Rigidizable Inflatable Antennas
- Space Agriculture
- Filtration Systems
- Debris Capture
- Strato Platforms

Global provider of advanced survival systems and equipment for Defence & Space Industry

TETHER AS PULLING CAPTURE TECHNOLOGY

Tether as a system of a pulling capture technology (net, harpoon) for ADR mission

Simple mechanisms
Simple rendez-vous
Versatile
Cheaper

Complex
Stack
Control

Simplicity before capture

Complexity after capture

TETHER HISTORY

A number of space tethers have been deployed in space missions with various degrees of success

1966 — NASA Gemini 11
First tether is space
30 meters long
Fully deployed

1992 — NASA/ASI TSS-1
Included Kevlar
20 km long
Deployed to 256 mt

1996 — NASA/ASI TSS-1R
Included Kevlar
20,7 km long
Deployed to 19,7 km

1997 — ESA YES
Dyneema
35 km long
Not deployed

2007 — ESA YES2
Dyneema (0,5 mm)
32 km long
Fully deployed

2008 — NASA MAST
Hoytether based
1 km long
Deployed to 1 mt

- Yellow: Electrodynamic
- Green: Momentum exchange & stabilization
- Red: Formation flying & pulling

PROJECT OVERVIEW

Project developed under a ESA Contract

ITT AO8258

Activities started in September 2015 and last 18 months

Today we are executing

Assembly Level Development Tests (ALDT)

after **TRR2-Dev**

(test end planned for Dec 2017).

CDR has been held in October 2016

TRP Objectives are:

1. to increase the **TRL** of the tether for ADR (primarily for the net) to **5-6** through an extensive environmental and functional test campaign.
2. To deliver **2x full-size stiff and elastic tethers** as fully functional **EM** with associated "data sheets"

Consortium

ARESCOSMO DEFENCE AND SPACE

GOTTIFREDI MAFFIOLI®

aviospace
an AIRBUS DEFENCE & SPACE company

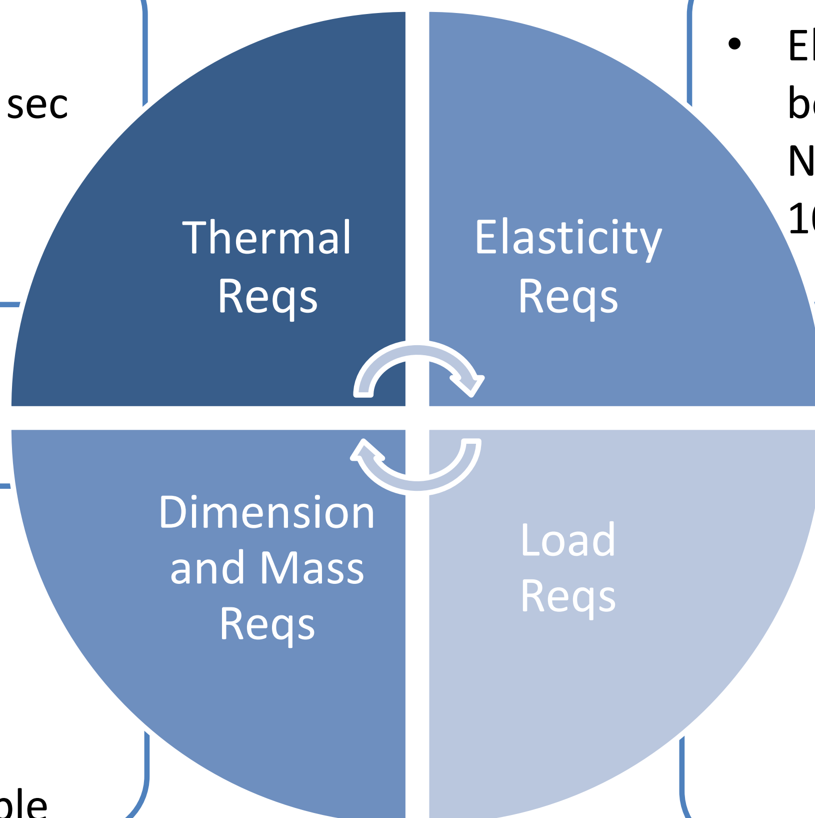
Elastic Tether

DESIGN CHALLANGES

What makes tether design (specifically elastic) a real challenge?

- Heat flux of 300 kW/m² for 1350 sec for the first 5 mt
- Flexibility

- Elastic constant between 50 and 100 N/m over a length of 100 mt



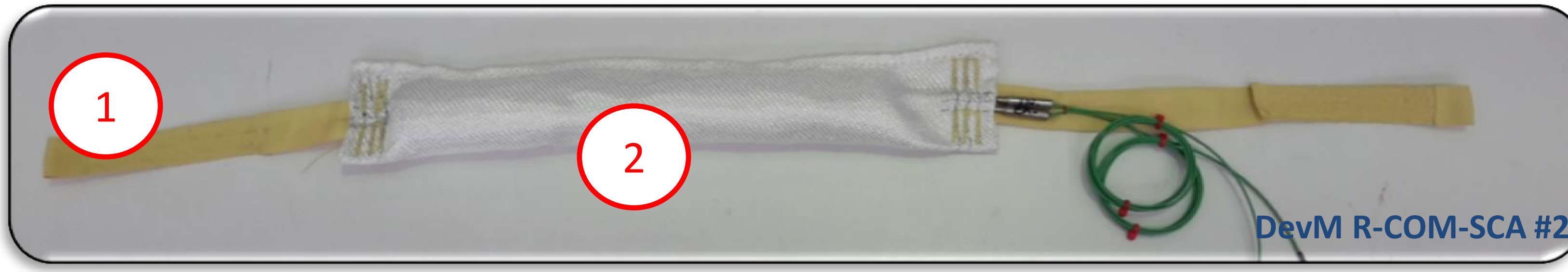
- Diam. of around 1 cm
- Section as much homogenous as possible
- As light as possible

- Peak operational load of 3800 N for 17 sec

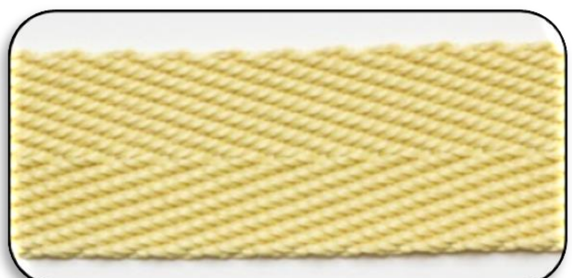
RIGID TETHER DESIGN 1/3

Rigid Tether is ribbon-based and it is composed of 2 parts:

- **Stiff Part** (1) for the whole length with loop interfaces with EST seams
- **Thermal Part** (2) on the first 17 meters with TUB and TER seams

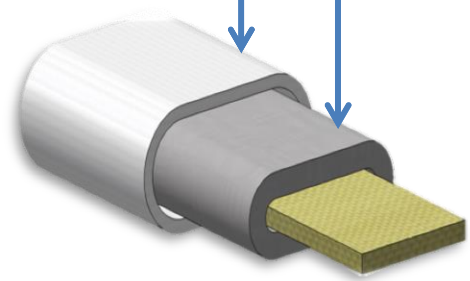


For the **Stiff Part** several high-strength and low flexibility fibers available in the market and with a known space heritage have been evaluated. At the end a **Kevlar** webbing 25 mm wide capable of withstanding 7750 N has been selected



For the **Thermal Part** several materials have been evaluated (metals, ceramics and ablative). At the end the designed protection system is:

- An internal layer of **15mm Silica webbing**
- An external layer of **3M Nextel fabric**



RIGID TETHER DESIGN 2/3

The webbing for the Stiff Webbing part has been chosen basing on material-level specifications:

- Breaking strength (**greater than 6600 N**)
- Operative temperature (greater that 400 C)
- Width and seamable area (between 15-38 mm)
- Good flexibility
- Good seamability
- Low mass

The minimum breaking strength values has been defined following the MoS verification approach used for textile materials with:

$$MoS = \frac{S_m e_j e_t e_a}{SF\ DUL} - 1 > 0$$

- Ageing Efficiency: $\varepsilon_a = 0,85$
- Temperature Efficiency: $\varepsilon_t = 0,9$
- Joint Efficiency: $\varepsilon_j = 0,95$
- Safety Factor: SF = 1.2
- Margin of Safety: MoS > 0
- Design Ultimate Load (from project specs): DUL = 4000 N
- Material strength (from material specs or Type-A basis from test): S_m

RIGID TETHER DESIGN 3/3

TER seam for R-family

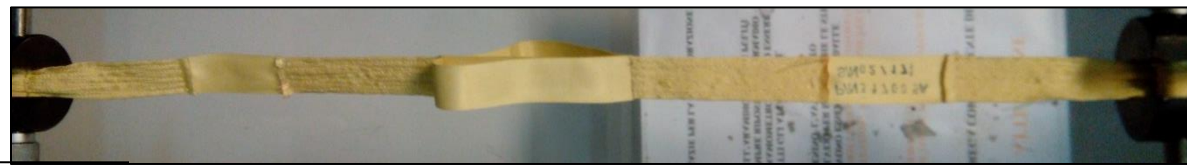
R-COM-SCA tensile results have shown that:

- Tensile strength is about **4500 N** with high standard deviation. This value is just above the req. F-03
- The ropture always happened in the *TER zone*

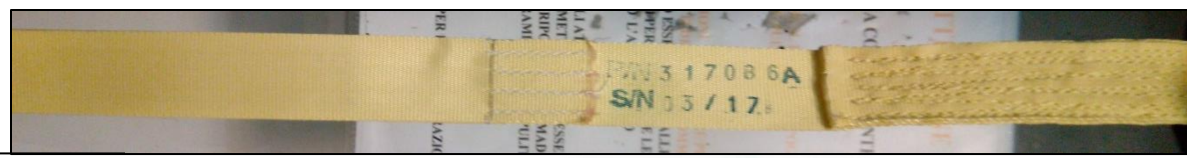
Objective → uncouple the mechanical behaviour of the kevlar webbing from the thermal protection joint.

Approach → to connect the kevlar webbing to the thermal protection (Nextel sleeve) will be used a kevlar webbing bridge.

Strong TER → 6400N



Soft TER → 6900N



No relevant changes in terms of elongation.
In all the tests the ropture zone far from TER seams

↓

Functional decoupling

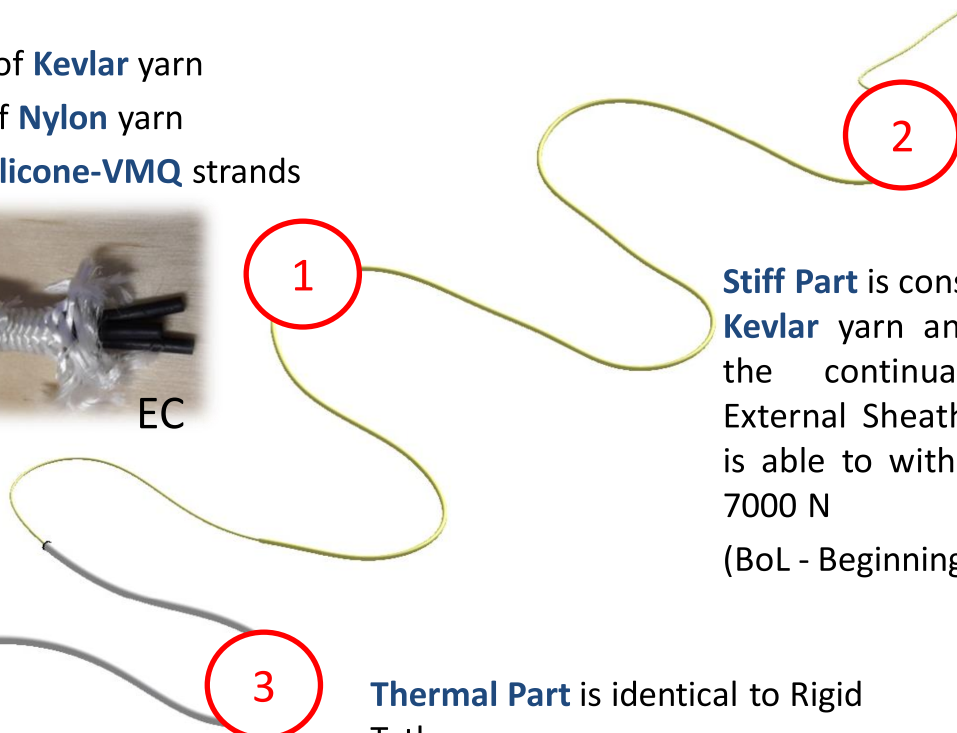
ELASTIC TETHER DESIGN 1/3

Elastic Tether is rope-based and it is composed by 3 parts:

- **Elastic Part** (1) for 3 meters (TBC)
- **Stiff Part** (2) for around with loop interfaces with EST seams
- **Thermal Part** (3) on the first 17 meters with TUB and TER seams

Elastic Part configuration is inherited from Bungee Cords. It is composed of:

- External Sheath (ES) made of **Kevlar** yarn
- Internal Sheath (IS) made of **Nylon** yarn
- Elastic Core (EC) made of **Silicone-VMQ** strands



Stiff Part is constituted of **Kevlar** yarn and it represents the continuation of the External Sheath. The stiff part is able to withstand a load of 7000 N

(BoL - Beginning of Life)

Thermal Part is identical to Rigid Tether

ELASTIC TETHER DESIGN 2/3

Transition vs. Max tensile load (MTL)

- From preliminary tensile test on kevlar sheath → **MTL = 7000N**
- From TEN01 (on ALDT) on **E-MEC-SCA** → **MTL = 4360N** (breaking in transition elastic/rigid)

Parameters to evaluate: **Braiding machine parameters**, **Integration parameters**, **Materials**

(From manufacturing tensile strength guide)

- IS Nylon sheath → nylon on entire length (until EST seam) =
  nylon gentle transition +
- EC transition/length (strands every 2 cm under load) +
- Addition of 2 kevlar yarns (no relevant changes in terms of diameter and marginally wrt weight) potentially +

New E-MEC-SCA model for ΔTEN01 tests

THERMAL ANALYSES

Thermal Problem

*The first 5 meters of the tether shall support a maximum heat flux of **300 kW/m²** for the duration of the burns*

*The 5 to 10 meters of the tether shall support a time-constant heat flux of **20 kW/m²** for the duration of the burns*

The 10 to 20 meters of the tether shall support a time-constant and linearly decreasing heat flux from 20 kW/m2 to 0 for the duration of the burns

Thermal Software adopted

SOLIDWORKS® Simulation 2015

Main Assumptions

Tether diameter << Tether length + Materials have low thermal conductivity → heat exchange in the length is negligible

Symmetry of the tether → No need to model entire cylinders. Ok to have only slices on the most interesting locations

Assumed 0.02 K m^2 / W for all thermal contact resistances (this value is typical for ceramic sheets, webbings, fabrics

Hot Case

The Hot Case is characterized from a sequence of 3 steps:

H1: A stationary condition with a heat flux from: **Solar + IR + Albedo**

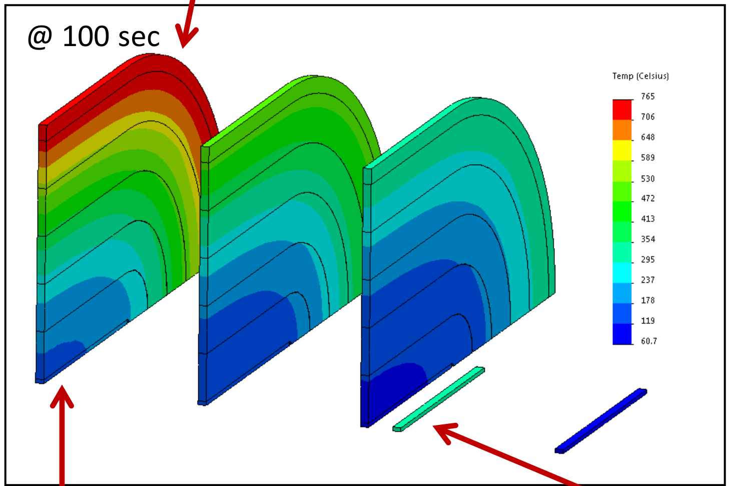
H2: A transitory condition of 1350s. A heating ramp with a heat flux from: **Thrust impingement + Solar + IR + Albedo**

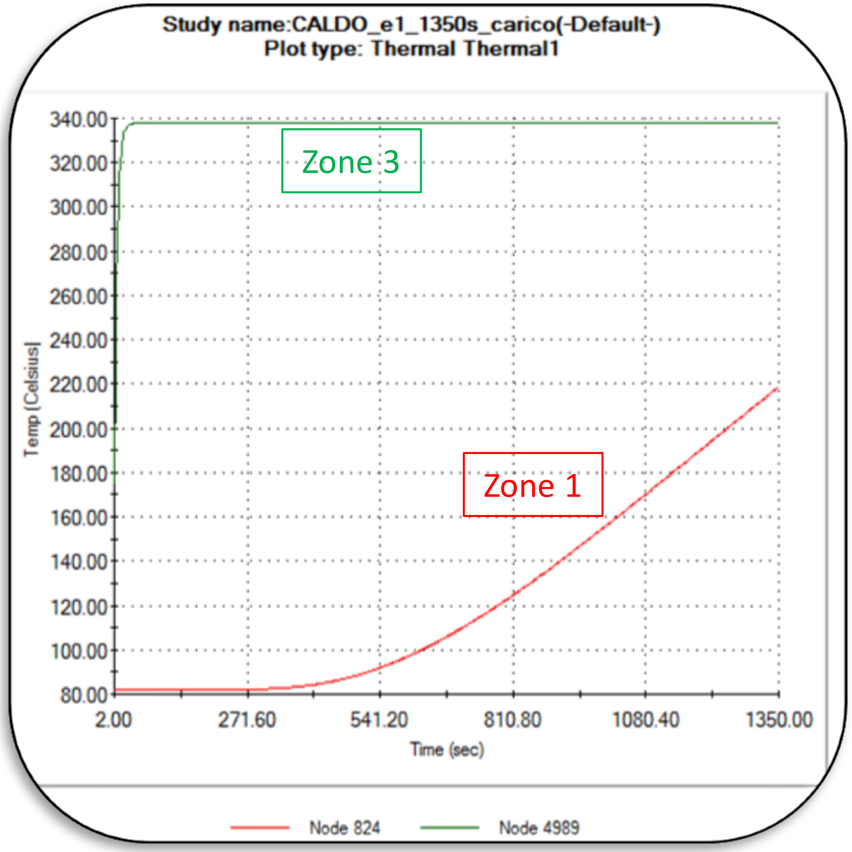
H3: A transitory condition until the stationary condition (some hours). A cooling ramp with a heat flux to: **Solar + IR + Albedo**

THERMAL ANALYSES

Rigid Tether
Hot Case
H2: Heating Phase

Zone 2: 3M Nextel reaches a peak temperature of 813°C





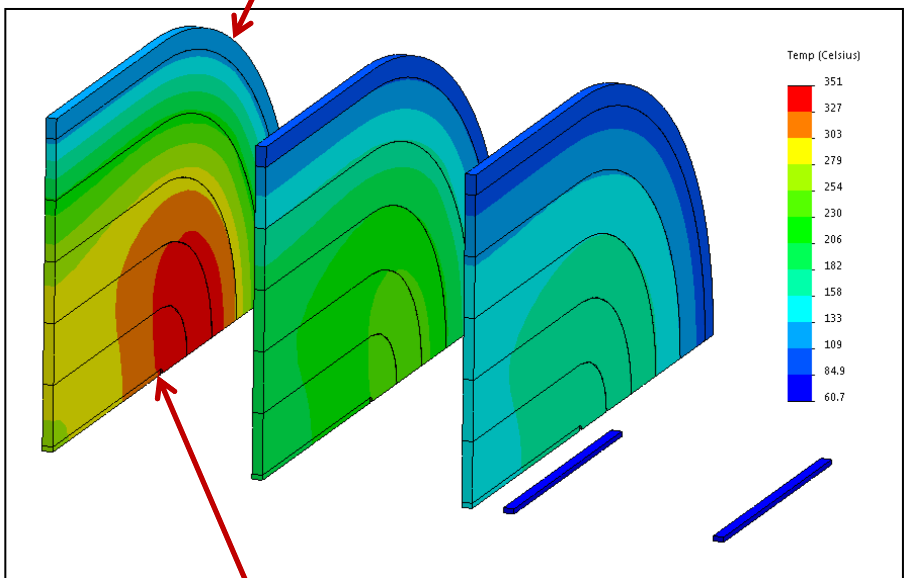
Zone 1: Kevlar covered by TPS sees growing temperature

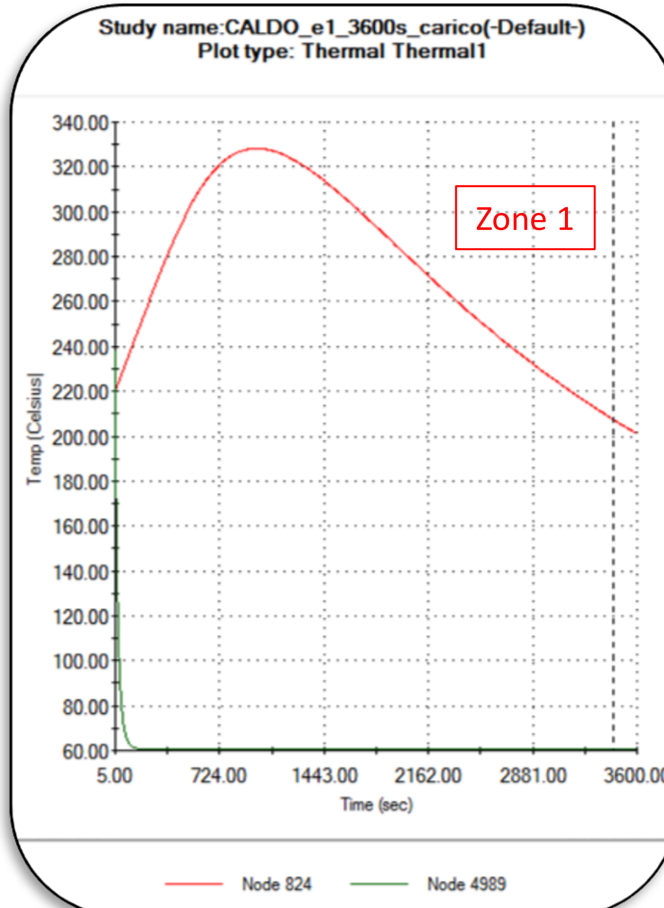
Zone 3: Kevlar after the TPS (17 meters) reaches the maximum temperature of 335°C and plateau at around 100 sec

THERMAL ANALYSES

Rigid Tether
Hot Case
H3: Cooling Phase

Zone 2: 3M Nextel temperature decreases

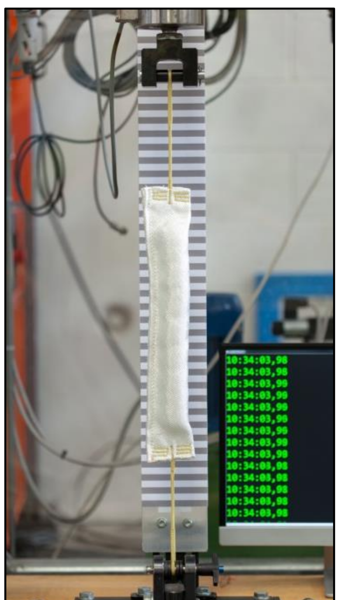


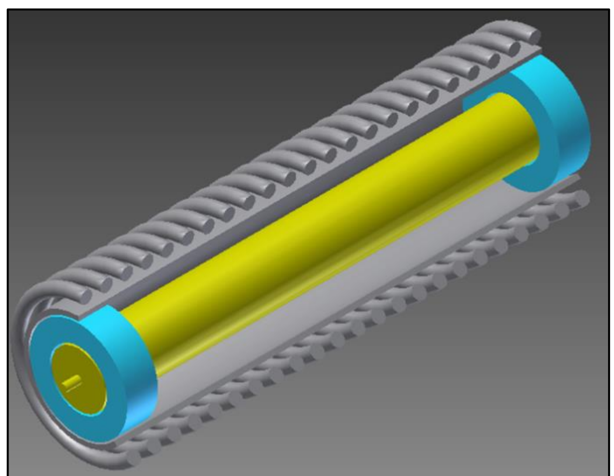


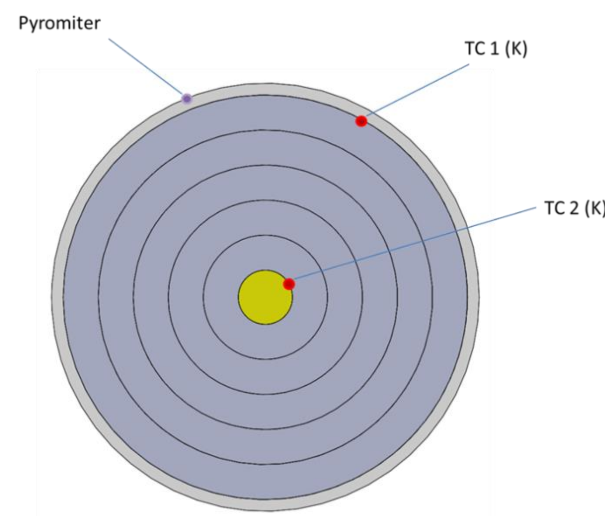
Zone 1: Kevlar covered by TPS sees its maximum of 330°C after approx. 1000 seconds after the end of the firing

ASSEMBLY LEVEL DEVELOPMENT TESTS

Assembly Level Tests Matrix Development		Objectives	Test Standard	Facility	Test ID	Rigid (R) Test Model	Elastic (E) Test Model	Number of Tests
Mechanical Tests	**Tensile Test BOL**	**Strength --> E, k Elongation --> E, k Note: up to rupture**	**Dedicated Procedure**	**CAI**	**TEN01 ΔTEN01**	**COM-SCA-#1**	**MEC-SCA-#1 THE-SCA-#1**	**9**
	Tensile Test EOL after Heat Flux (Heat Flux according to req. E.1 and E.2 for 1350 sec)	**Strength --> E, k Elongation --> E, k Note: up to rupture Characterization of: - Mass**	**Dedicated Procedure**	**CAI (Heat Flux: AAC)**	**TEN02**	**COM-SCA-#2**	**THE-SCA-#2**	**6**
					Total Number	-	-	15

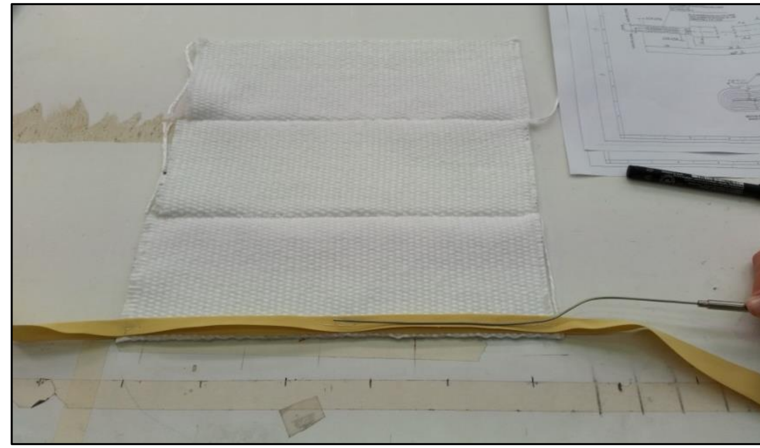


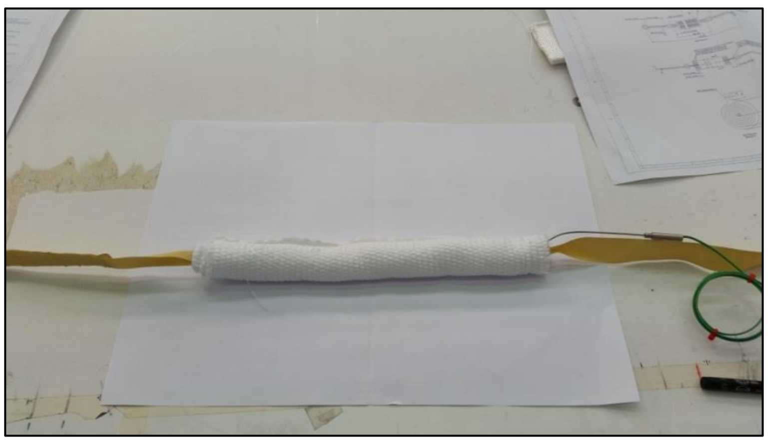


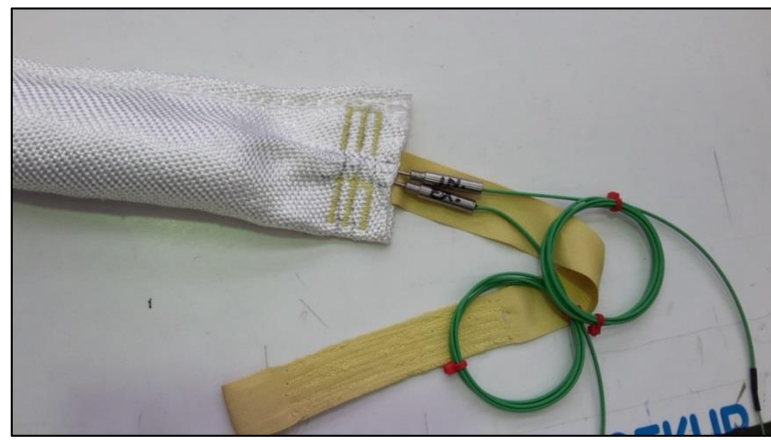


MODELS MANUFACTURING PROCESS

Example: **R-COM-SCA#2** for TVA and TEN-02







NEXT STEPS

Next activities in TRP **"Elastic Tether Design and Dynamic Testing"**

Assembly Level – Development Tests (from June to December 2017):
Completion of Development Tests on scaled and partial models (TEN01 and TEN02)
PTR2-Dev and possible revision of the scaled and full models design

Assembly Level – Qualification Tests (from January to February 2017):
Manufacturing of scaled and full size models (including EM) for the Qualification Tests
TRR2- Qual
Execution of Assembly Level – Qualification Tests

Between PTR2- Qual and Final Presentation (September-October):
PTR2-Dev and possible final outcomes and suggestions for the tethers design
Preparation of Development and Qualification Plan and Final Documentation (WP8000)

Final Presentation is planned for the **end of March in ESTEC**.

Thanks for the attention!