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Sails … and more “Made in Luxembourg”

Technical day on ‘deorbiting strategies’ (Estec - 17/03/2015)

Outline

- Quoting ESA:

> The Technical Day is focused on presenting and summarizing European knowledge and technology developments in the areas of drag augmentation devices and solid rocket motors de-orbiting systems. The objective of the technical day is to shape recommendations for future research in this area through highly interactive sessions which are designed to produce actionable results.

- This LuxSpace contribution to:
  - present Luxembourg's expertise in (solar, drag, …) sails
  - present LuxSpace's projects relating to (…) sails and deorbiting with these
  - make recommendations for future research in the areas of drag augmentation devices

Expertise, origin and quality

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- In Luxembourg, when industries are particularly proud of their products, their local expertise and their quality, they can apply for the national label:

- LuxSpace intends to apply soon for this label, considering our established expertise and products in the fields of:
  - (Large) sails for solar/drag/power and other sailcrafts
  - Spaceborne Sails containers
  - Sail-to-Structure Interfaces (SSIF)

www.made-in-luxembourg.lu

Expertise build-up

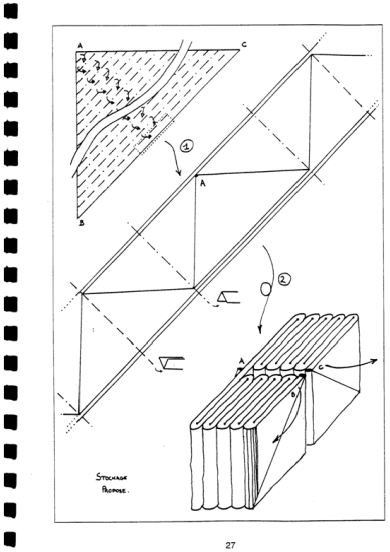
- The following projects contributed over more than 20 years now to build-up the LuxSpace expertise on (drag)sail technologies:
  - Oct. 1993 – Mar. 1995 : Voilier Solaire Européen (VSE)
  - Nov. 1996 – Jun. 1997 : Daedalus (for ESA)
  - 2005 – (during) 2007 : Libellule (for AMSAT-F)
  - 2008-2013 : Solar Sail Materials (SSM, for ESA)
  - 2014 : E-SAIL Phase B1 (for ESA)

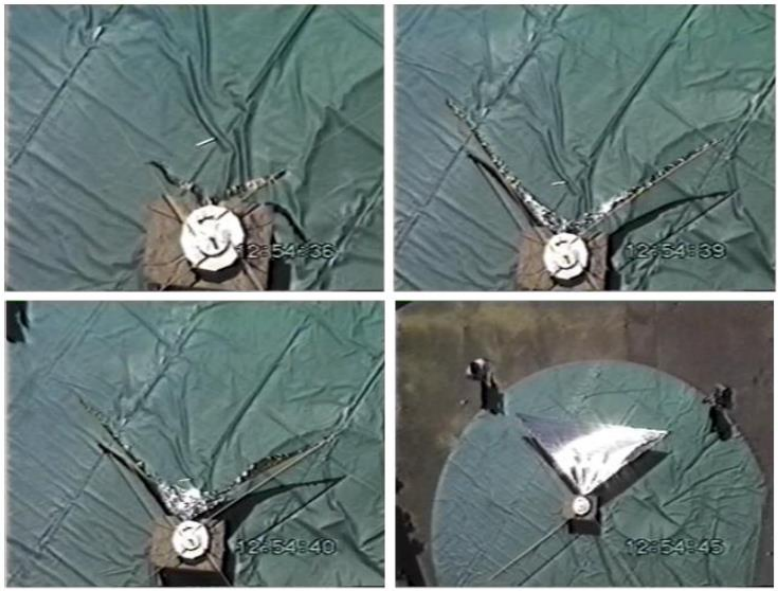
VSE (1)

- In 1991, the « Voilier Solaire Européen (VSE) » non-profit association was established as a supportive arm of U3P to develop the technologies enabling / promoting the photonic propulsion in Europe.
- Clearly identified as a starting point / critical technology to investigate, a feasible and safe folding/deployment concept for large sails was ideated (by me) in late 1993 and tested during 1994 with positive conclusions wrt spaceborne use:

Original drawing of the « VSE » folding scheme:

This folding scheme was later also renamed by (anonymous) as « Frog Legs » folding scheme.





VSE (2)

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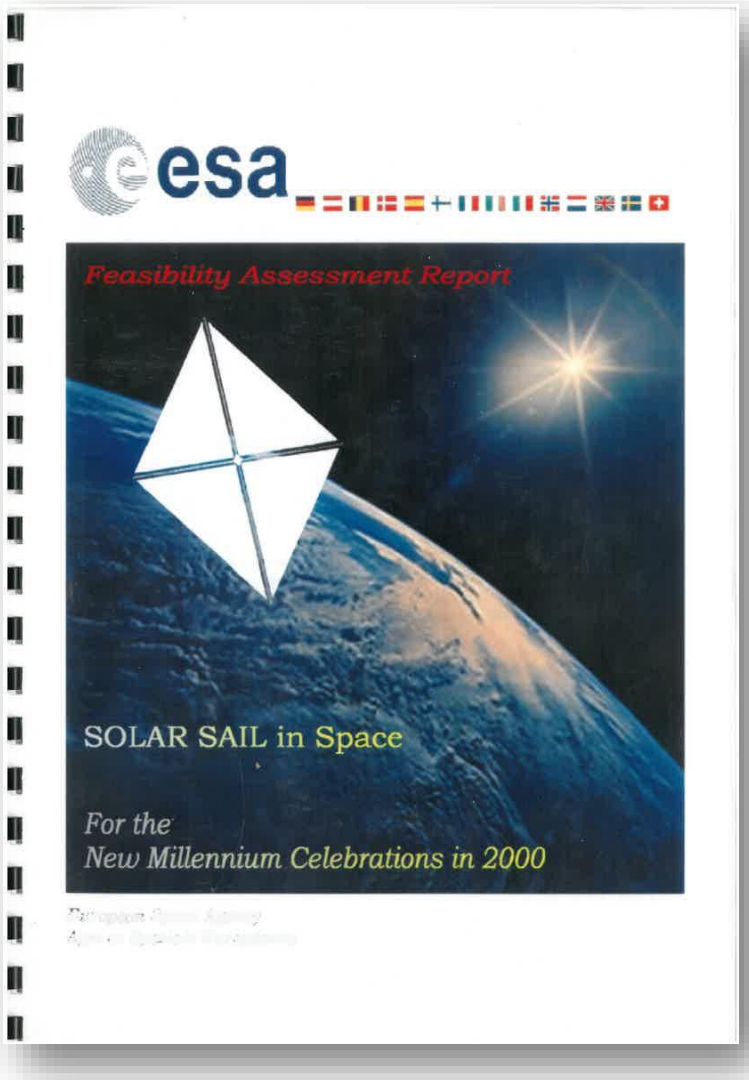
- For the scope of this Technical day on 'deorbiting strategies' it is here clarified that no patent has ever been requested for this folding scheme.
- Indeed, being the intention of VSE to enable and promote the use of photonic propulsion in Europe, the approach was not to hide things but instead to widely publish our findings …
- As such, we publicly presented this folding scheme to IAF 1994 and documented it in the respective paper:
- *IAF-94-I.1.177 : "Structural Advances on the European Solar Sail" ; L. Perret, F. Dalla Vedova, D. Denaux, A. Esterle – Le Voilier Solaire Européen*

- Use of this folding scheme for (solar) sailing applications is encouraged but … please with appropriate reference to the above paper and its Authors. Thank you
- About this, I would like to thank here Clyde Space, whishing them All the Best for their « AEOLDOS » product for CubeSats.

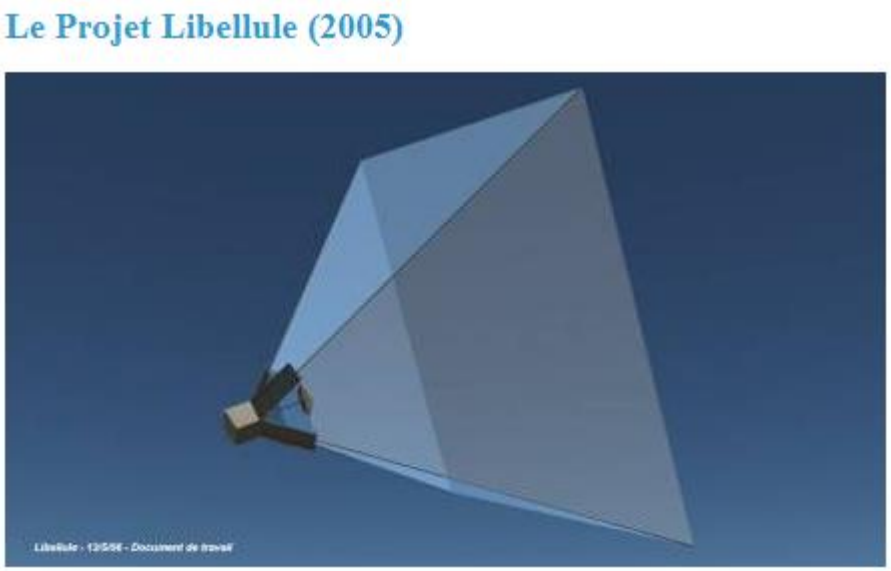
Daedalus

- Daedalus was an ESA Phase 0/A project aiming at investigating the feasibility of deploying in LEO a small sail for the New Millenium Celebrations of 2000.
- The study concluded about technical feasibility of such project but ...
- ... the biggest concern we raised within ESA (and outside in the Astronomical Community) was about the fear of having terrestrial based observations being disturbed by sail-reflected light !
- This concern should be taken into account when selecting the protective coatings of dragsails ...



Libellule

- First experience of deorbiting with dragsails was gathered with the support given to AMSAT-France to their Libellule (Dragonfly) project.
- Offered support related to the sails, their storage and deployment



Solar Sail Materials (SSM) (1)

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- The LuxSpace SSM project objectives were to make progresses on sail materials, their assembly and integration for future Advanced European Solar Sail missions.

- Out of all, major progresses were expected on :
  - Identification of the reference film materials to consider for European projects.
  - Thinning of the reference film material(s) to 3 microns or less.
  - Identification of suitable film coatings (reflective and emissive) and protective overcoats
  - Identification of an environmentally resistant assembly concept and related adhesive(s)
  - Selection of a preferred sail-to-structures fastening concept

- Although focusing on technologies necessary to assemble efficient and reliable sails, the SSM project investigated also some key system aspects relating to :
  - Sail-to-Structure Interfaces (SSIF) e.g. sail tensioning devices and sail containers
  - Optimal tensioning strategy, under 1g
  - Scalability of results, from 1g observations and simulations of small scale mock-ups/breadboards up to large scale operational sails in orbit.

Solar Sail Materials (SSM) (2)

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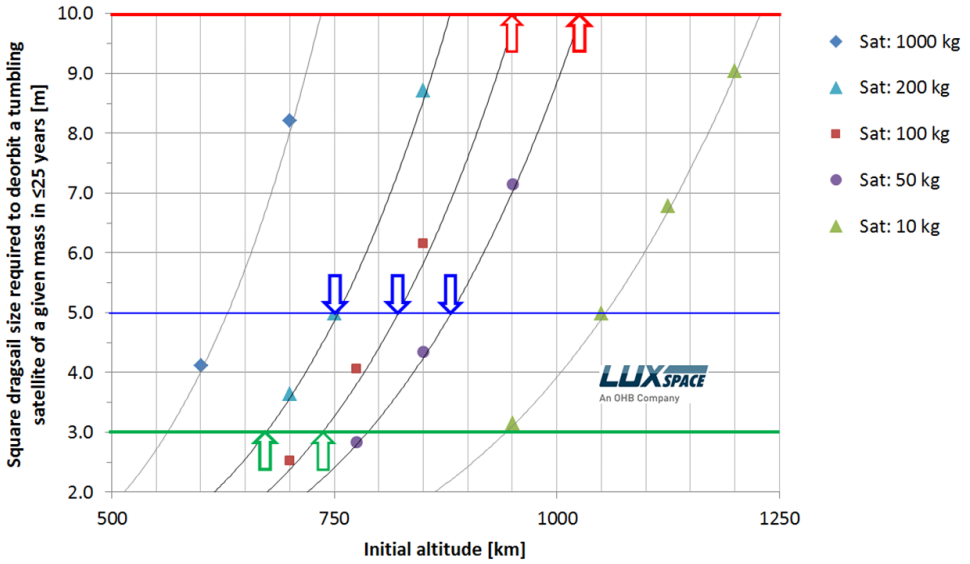
- The LuxSpace-led SSM project made key advancements in developing and qualifying feasible technologies and concepts applicable for future sails of advanced European solar sailcraft missions :
  - For what relates to the sails, the SSM project was indeed able to define a mix of suitable (film, coatings, assembly) materials featuring an overall Sail Film Areal Density σ_{Film} compliant with the GeoSail requirement of ≤ 6 g/m^2
  - According to analyses and tests performed with SSM, the best sail fastening solution is made with Taped (Tubed) Strings and Rigid Triangle fasteners, holding the sail according to Tip Holds.
  - SSIF elements have been identified and for each of them first concepts have been proposed (especially for the sail container)
  - For a complete 7,5 microns European sail, a TRL of [5,7/2] was estimated at the end of the SSM project. For a complete ≤ 3 microns European sail, the TRL should be [4,9/2]. The SSM SSIF's TRL is today estimated to be [5,7/2] (using the ESA TRL format [Avg/Min])
  - Thanks to the validation of FEM simulations with 1g observations/measurements on small scale mock-ups/breadboards, the scalability of FEM results to large scale operational sails in orbit is now ensured.

E-SAIL

- Intensive investigations on deorbit means have been performed during the Phase B1 of this ESA ARTES 21 programme:
  - Propulsion is expensive for smallsats ...
  - Tethers are definitely not encouraged above the ISS orbit ...
  - DragSails are appealing

- LuxSpace made and combined numerous simulations with all three Agencies tools to derive this:



DragSail prototype

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- LuxSpace developped and tested recently with success a complete and very simple (remember KISS) DragSail prototype suitable for 30 kg microsats
- Images of the product will not be disclosed here but …
- Out of 25 deployment tests, we could observe three failure modes
  - Two of these are only partial as they allow a correct deployment of the sail
  - The last failure mode implies that the sail is deployed but will not be able to perform (for long) its function
  - However, out of the 25 deployment tests, 92% led to a functional sail
- Based on these excellent results, LuxSpace is now pursuing this development with increased sail and boom dimensions.

Catch&Carry

- LuxSpace is currently performing a Phase 0 study to identify opportunities for Luxembourg's Entities to further develop (in Space) their robotic capabilities.

- The Catch&Carry mission considers a deorbiting with DragSails

Next @LuxSpace

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- LuxSpace should soon support the CleanSpace initiative on deorbit sails with a study on dedicated GNC for DragSails

- LuxSpace should also soon start another project under ESA to risk mitigate the use of sails for a really particular application

- LuxSpace will pursue with the development of (spaceborne) sails « Made in Luxembourg » with the hope that these could be part of a first future European (solar) sailcraft mission. Such mission would rely on the various european developments performed by several Countries, including … Luxembourg.

Recommendations

- Taking the opportunity given by this Technical day on ‘deorbiting strategies’, LuxSpace, based on its long experience in sail membranes (and sailcrafts) recommends:
  - Pursuing activities targeting the Sustainable Development of Space
  - Pursuing European-wide developments related to (drag) sails
  - Paying attention to possible DragSails light reflections toward Earth and possible disturbances to terrestrial observations for Astronomy.
  - Fostering European collaboration for future (solar, drag, …) sails missions

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Thank you for your attention

Wishing us All a fruitful collaboration