Space Passive Component Days

Space Harness Design Optimization

Opportunities on ECSS Improvement

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Summary

The spacecraft's harness is more & more complex and highly constrained.

It could exceed **50 000** connections**, 200 kg** and **20km** of wire length.

It becomes a critical design driver for modern spacecrafts.

To dramatically reduce the harness complexity and safely improve its efficiency, a "quick-win" solution would be to revisit the derating rule on wires & cables.

Studies have been started using dedicated thermal simulation software to pave the way toward a **revision of the ECSS derating rules**.

The Essence of Harness

The Harness provides

Connectivity

complying with

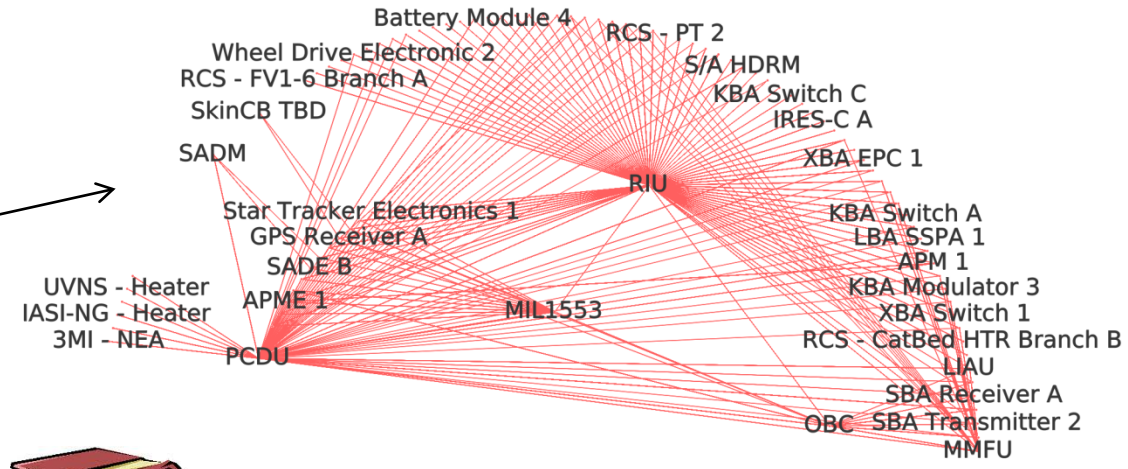
Electrical & other requirements

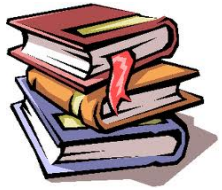
accross the

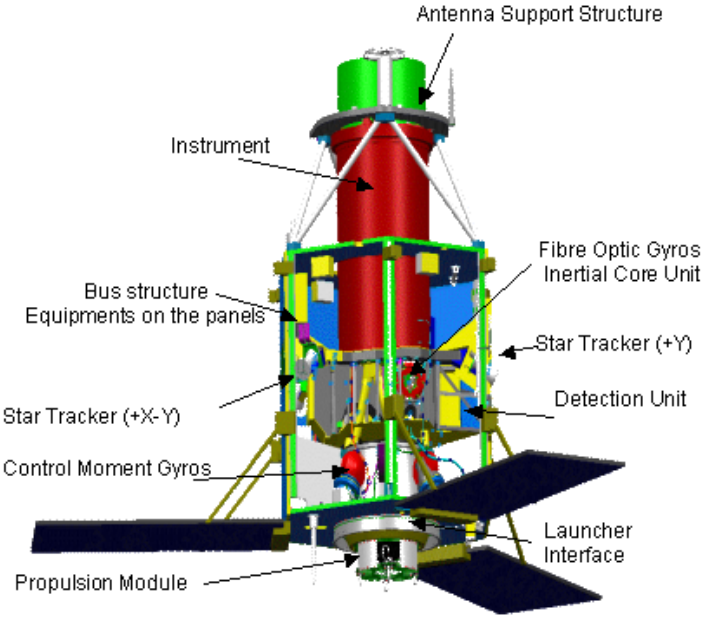
Spacecraft 3D environment

using

Qualified Parts, Materials & processes







A CROSSROAD OF REQUIREMENTS

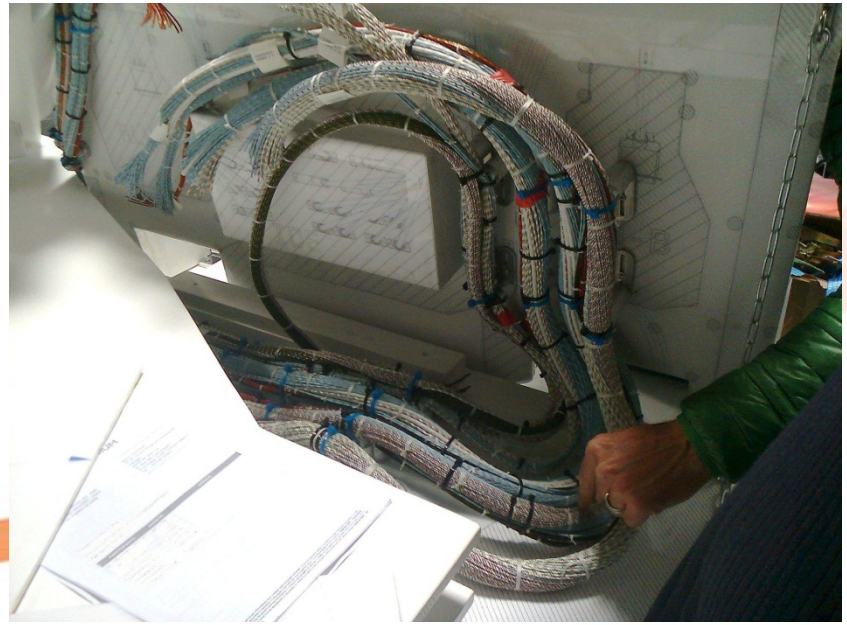
A trend to critical mass & complexity

The evolution of scientific and commercial space missions results in a constant increase of the spacecraft's power and complexity.

Both are directly impacting the harness design and performance:

- Large, powerful satellites require long wires with large sections, increasing the mass of the harness.

- Small satellites impose compact harnesses and complex inter-panels connections (e.g.: hinges).



Harness Feasibility: a Critical Design Driver

The design of the harness imposes nowadays very significant efforts in concurrent engineering with the system architects to find out and validate harness solutions.

This generates lots of reworks on the harness definition and the spacecraft accommodation with high cost and schedule impacts.

A deep optimisation of the harness is now mandatory to achieve the spacecraft's mission with the required performance.

How to optimize the harness

Power Distribution

Unit's & Heaters supply

Pyro, Relays, RF switch commands

Data Transmission

Data buses,
Analog & digital commands & acquisitions

Easier

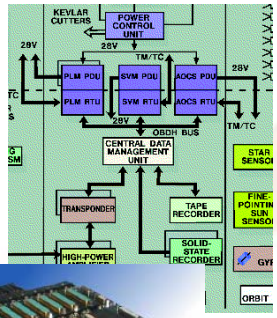
Optimise the use of harness components

Hard

Develop & Qualify new harness components

Hard

Change the Spacecraft's electrical architecture



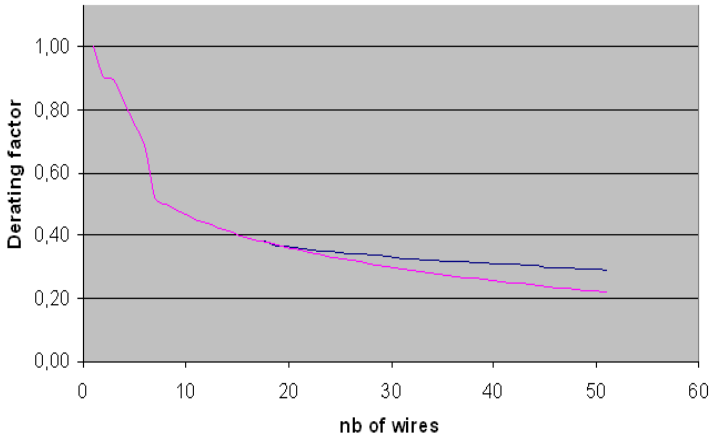
Hard

Change avionic equipments

A Quick-Win: revisit ECSS-Q-ST-30-11C wires & cables derating rules

High saving can be expected because:

- The derating factor is very severe, especially for conductors within bundles
- The derating factors are based on worst case configurations:
  All active wires in the bundles are supposed to be fully loaded at the same time.
- Inactive wires are supposed to increase the temperature of the bundle, which doesn't seem to be always true.



How to improve the ECSS derating requirement ?

- The rating factor is mainly based on the acceptable temperature on the wire, which depends on:
  - The environment conditions (temperature / solar flux / bundle protection)
  - The load condition (current in each of the wire & ohmic resistance)
  - The physical constitution of each bundle (shape, protection…)

- Each of these elements can be considered as an opportunity for harness sizing optimisation and they are not currently fully taken into account in the ECSS.

Opportunities & Constraints not fully detailed in Current ECSS

Various arrangement of sub-bundle

Unequally loaded wires within bundles

Details of margins

Flat Bundle

Longitudinal conduction factor

Bundle protection (double insulation, protective braids, overshields)

Customize current rating to all environment conditions

Radial conduction factor (for large sections)

Rules applicable for twisted pairs, shielded wires & cables

Saving Evidence

Astrium has developed a significant experience and software tools for thermal analysis on harness bundles, validated through test campaigns.

Analyses had to be performed on recent programs to allow the achievement of very challenging harness design.

They allowed more than **25% mass saving** on the power harness, without any deviation on the harness acceptable temperature.

Studies performed by NLR using simulations & tests did also confirm significant mass saving opportunities on derating rules.

Bundle thermal simulations (Astrium)

Thermal Tool for Cables

Environment

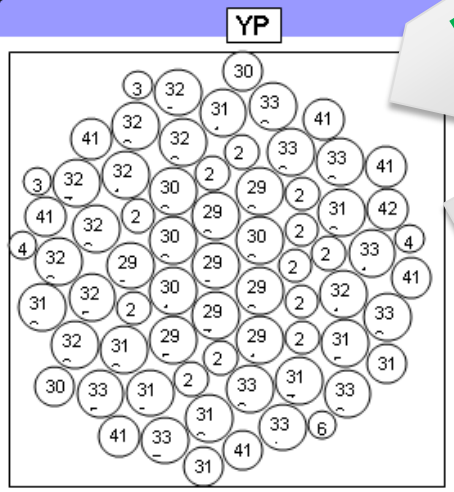
Bundle's shape

DC Currents In the wires

Run process: OK

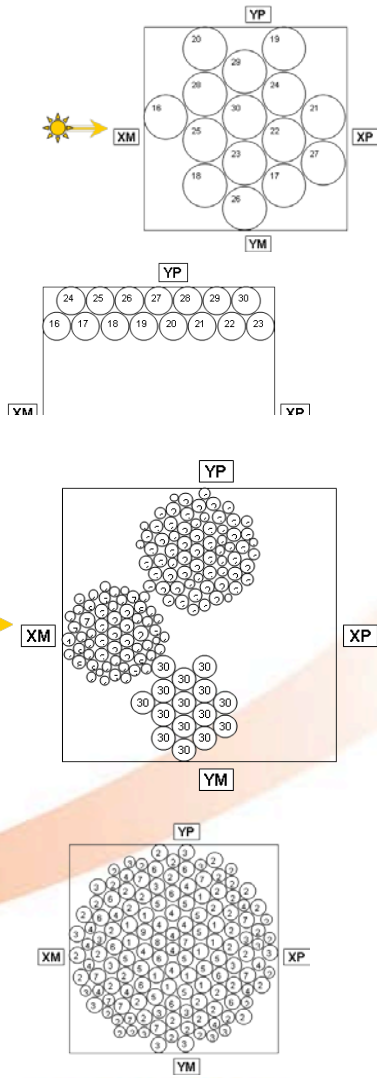
Environment Input Data

T_XP (K)	328,15
T_XM (K)	328,15
T_YP (K)	328,15
T_YM(K)	328,15
SOLAR FLUX (W)	0
SOLAR ANGLE (°)	180
EXTRA ISOLATION	OFF
RADIUS (m)	0,006365



Cables Output Data

Cable Number	T Conductor (K - °C)		T Dielectric (K - °C)		Solar Power (W)	Electrical Power (W)	I (A)
61	345,09241	71,942407	345,089254	71,939254	0	0,005057	0,2
208	356,0883	82,9383	356,053855	82,903855	0	0,072418	1,068
209	355,5096	82,359596	355,475214	82,325214	0	0,072286	1,068
210	355,27573	82,125732	355,241375	82,091375	0	0,072233	1,068
211	355,77324	82,623237	355,738826	82,588826	0	0,072346	1,068
212	354,02614	80,876136	353,991916	80,841916	0	0,071948	1,068
213	356,25959	83,10959	356,216082	83,066082	0	0,091475	1,2
214	355,60888	82,458879	355,574486	82,424486	0	0,072309	1,068
215	353,67664	80,526641	353,642458	80,492458	0	0,071868	1,068
216	353,65466	80,504664	353,620483	80,470483	0	0,071863	1,068
217	353,11061	79,960614	353,076492	79,926492	0	0,071739	1,068
218	352,44274	79,292742	352,408693	79,258693	0	0,071586	1,068
219	357,13625	83,986251	357,092623	83,942623	0	0,091727	1,2
292	359,17461	86,024611	359,096976	85,946976	0	0,233507	3
293	356,57459	83,424586	356,497581	83,347581	0	0,231613	3



Way Forward

ESA initiated a study starting in September 2013 granted to the National Aerospace Laboratory of The Netherlands and Astrium, to review the existing standards and assess the existing simulation softwares.

The results should allow starting a new study in order to establish by analysis, simulation and validation tests a proposal for an update of the ECSS derating rules for wires & cables.

Let’s get flying light harnesses !