● Configuration : **D3-Brochure RP-ADST-1000437290**
● Issue : 01 ● Date : 11/12/2018

HARNESS IMPROVEMENT PROJECT:
D3 Brochure

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DOCUMENT CHANGE LOG

ISSUE/ REVISION	DATE	OBSERVATIONS
01/00	11/12/2018	First issue

HARNESS IMPROVEMENT PROJECT

Due to an increasing power and complexity, electrical harnesses in aerospace systems require mass and volume optimization. The harness mass performance is driven by the ampacity (or current rating), that is the maximum current a wire or cable is able to carry without exceeding its maximum operating temperature. This current depends on the environment (pressure, temperature…), the wire's physical characteristics (gauge, dielectric, overall diameter…) but also on the number of wires routing in the same bundle.

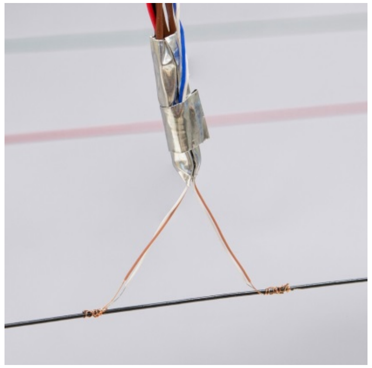
An ESA financed study completed in 2014 highlighted that:

- The sizing rules for wires and cables defined in the ECSS derating standard (ECSS-Q-ST-30-11C) lead most of the time to over-conservative harnesses and is mainly based on a single environment temperature.
- The different international standard (ECSS, NASA, JAXA) are derived on the single wire current as defined in MIL- STD-975L, but they are not consistent for the environment maximum wire temperature or bundle sizing rules, and their justifications are not always available.
- Simulation tools can help to optimize the sizing of wires routed in bundles especially when they are un-evenly loaded or made of mixed gauges.

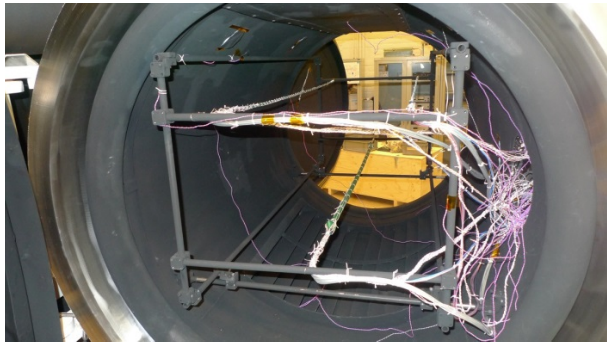
For this reason, in February 2016 ESA initiated a study in the frame of the Technology Research Program (TRP).

The aim of this project, which has been led by Airbus Defense & Space with the Netherlands Aerospace Centre as subcontractor, is to recommend improvements of the ECSS de-rating standard and to encourage the use of validated thermal models for space harness design optimization.

This study, completed in December 2018, was presented in ICES2018 conference and SPCD 2018.

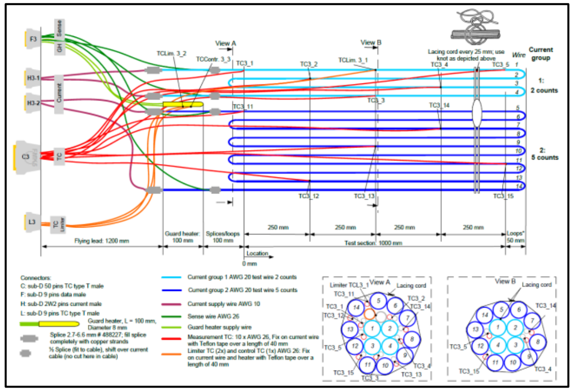


TC connected to a wire for conductor and dielectric temperature measurement.
Heat losses are suppressed with a heater.



Cable bundle batch located at NLR in the Harness Derating Test Facility

As much as 20 wire samples have been selected, covering most of the wires used in space: gauges, types of dielectrics (polyimide, Peek, ETFE, PTFE), core material (copper, aluminum and stainless steel), as well as bundles configurations for usual flight cases: six bundles from 6 to 200 wires .



Definition and Instrumentation of a Bundle

Hundreds of test were performed in vacuum using the NLR's Harness Derating Test Facility at different environment temperatures (-50°C, 25°C and 100°C), to measure the current needed to obtain maximum wire temperature in steps of 25°C.

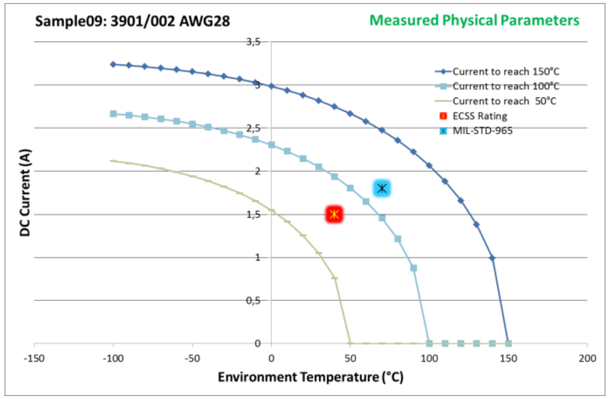
The following physical parameters were recorded for each sample at steady state:

- Resistance of the wire
- Electrical current injected in the tested wire
- Core and Dielectric outer surface temperature, at multiple locations within the sample.

This 3-year study resulted in a proposition for refinement and an extension of the current derating standards using a validated formula for single wire sizing and a simple table of derating factors for bundle sizing.
The new formulation, clearly based on the physics of power dissipation and thermal exchanges, substantiates the current rating of single wires by taking out margins while addressing a larger range of environmental conditions and wire types.

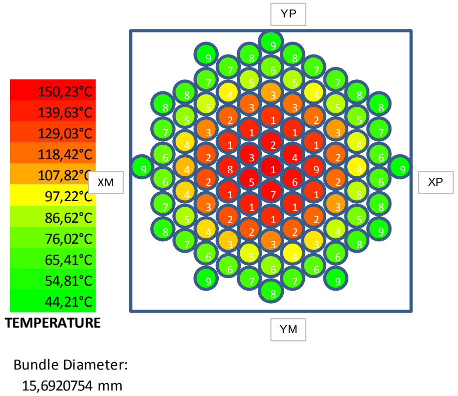
$$I_{sw} = \sqrt{\frac{\varepsilon.\mathrm{D}.\pi}{\mathrm{R_{Tref}}}} \times \sqrt{\frac{\sigma(\mathrm{T_{wire}}^4 - \mathrm{T_{env}}^4)}{1 + \mathrm{C_T}(\mathrm{T_{wire}} - \mathrm{T_{ref}})}}$$

I_{SW}	Single wire current for the considered wire gauge [A]
D:	wire's external diameter [m]
σ:	Boltzman constant = $5{,}67 \cdot 10^{-8}$; [Wm-2K-4];
I:	Electrical current [A]
T_{wire}:	Temperature of the wire, assuming no significant thermal gradient between the conductor and the dielectric [K]
T_{env}:	Temperatures of the environment [K].
T_{ref}:	Reference temperature for the resistance [K]
ε:	Thermal Emissivity [-]
R_{Tref}:	Ohmic resistance per unit length at T_{ref} [Ω/m]
C_T:	Coefficient of temperature for the wire resistance (related to T_{ref}) [K-1]



Example of ECSS and Nasa Standards compared to formulation.

Thousands of thermal simulations were performed to correlate the models with the test results, making possible to recover the justification of single wire sizing rules and to propose an upgrade of the rating and derating rules for wires and cables in free vacuum that are defined in the European standard.



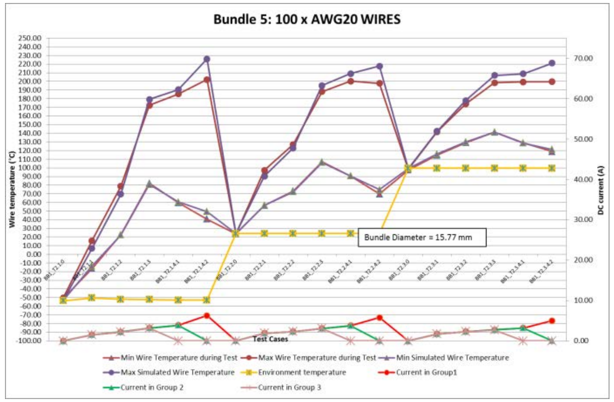
Thermal simulation result with loaded wires in the centre and passive wires at the surface

Count Of Wires	1	2	3	4	5	6	7	8
Bundle Derating Factor	1.00	0.90	0.81	0.76	0.71	0.66	0.62	0.60

Count Of Wires	9	10	15	25	50	100	200	300
Bundle Derating Factor	0.59	0.57	0.49	0.40	0.29	0.21	0.15	0.12

Bundle derating factors from 1 to 300 wires.

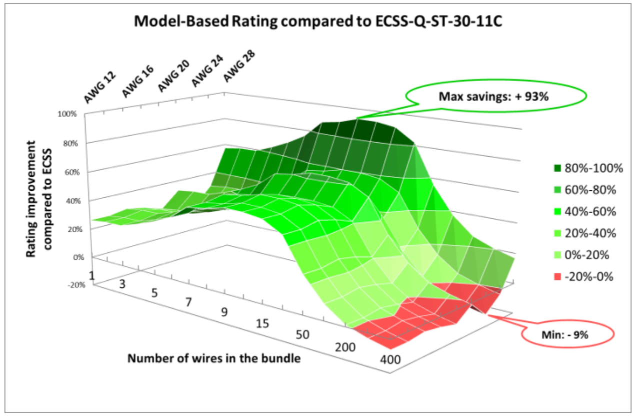
The new rules improve the precision of the wire's thermal model. In addition, they allow taking into account the environment temperature and the exact physical characteristics of the wires.
In most cases a mass and volume reduction of harness bundles is to be expected. Mass savings in the range 20% to 50% could be expected on power bundles depending of the use cases. The savings on current sizing exceed 90% for some of the wires.



Comparison of Simulated and Measured Extremum Temperatures in the bundle.

The assumptions for application of the new derating rules are more clearly defined and justified.

In addition to the new single wires and bundle derating rules, it is now proposed to allow thermal simulations for harness sizing based on worst case wire temperatures, provided that the simulation software complies with specified criteria. This approach permits specific harness configurations and additional significant optimizations.



Model-based current sizing compared to the European standard.