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FAILURE ANALYSIS ON OPTICAL FIBER ON SWARM FLIGHT PAYLOAD

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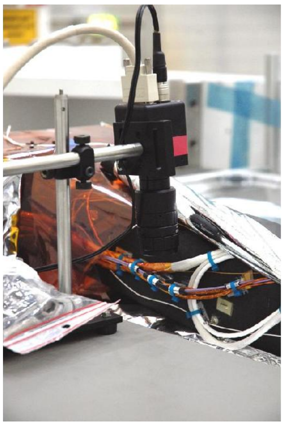
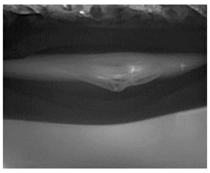
Introduction

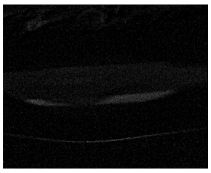
Failure analysis on optical components is usually carried-out, on standard testing devices such as optical/electronic microscopes and spectrometers, on isolated but representative samples. Such analyses are not contactless and not totally non-invasive, so they cannot be used easily on flight models. Furthermore, for late payload or satellite integration/validation phases with tight schedule issues, it could be necessary to carry out a failure analysis directly on the flight hardware, in cleanroom. Therefore, the CNES (Centre National d'Etudes Spatiales) department "Laboratoires & Expertise" has explored the capability to bring classical imaging and physical characterization measurement systems close to the payloads. The goal is to get as soon as possible a maximum of non-invasive information in parallel with laboratory analyses and simulations, to help project teams to take good decisions. The optical fiber of SWARM instrument (SWARM is an ESA "Earth explorers" program: constellation of 3 satellites to study the magnetic field) "FM1A" (Flight Model 1A), guiding the light from the laser to the magnetometer, has been damaged during assembling and testing operations. This poster shows observations and analysis that have been done at CNES (France), and also on the flight model at IABG (Germany) with the collaboration of ESA (European Space Agency).

Infrared inspection on flight model





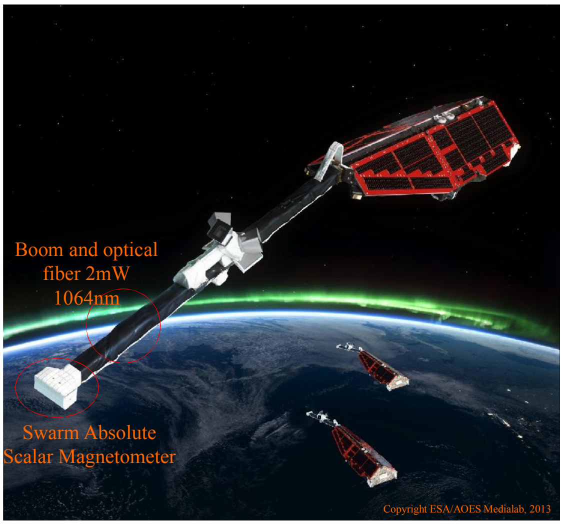
IR image under room light



IR image, room light off and laser on

Infrared InGaAs camera (900 – 1700 nm) shows a very small amount of light escaping from the jacket with 2mW of power injected in the fiber. A calibration of the sensitivity of the camera in our laboratory, in these conditions, shows that this amount of light is insignificant (less than few ppm) and confirms that there is no cracks in the optical fiber.

Damaged area on the fiber



Boom and optical fiber 2mW 1064nm

Swarm Absolute Scalar Magnetometer

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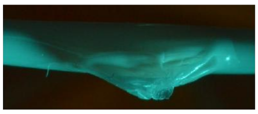
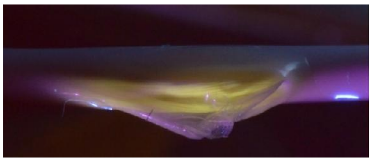
UV inspection on flight model

Absorption and emission tests have been performed under UV/visible light on the different layers of the optical cable and it turned out that the jacket was an excellent absorbent at 450nm and quite transparent at 365nm for low thickness. In addition, the aramid fibers have a very good fluorescent yield at 365nm with a yellow reemission, and the third thermoplastic layer (sheath) is fluorescent in the red part of the spectrum.

On the following pictures and from two different views, the jacket absorbs the 450nm excitation light, and then behaves as a source at higher wavelengths. It is no longer transparent. This confirms that a thin film of fluoropolymer is still covering the aramid fibers.



At 365nm radiation excitation, the fluorescence yield is very high for the aramid fibers and low for the fluoropolymer. This confirms that the aramid fibers are not broken despite an important shifting (extension) in the damage jacket; nevertheless, this may involve tensions in the optical fiber.



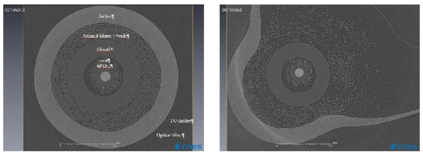
To conclude concerning the UV, visual, IR inspection on flight model, we know that the optical fiber is not affected by latent cracks. They would involve a measurable loss of light escaping from the core with this InGaAs camera. These cracks have also been reproduced in our laboratory and the amount of light is much more important than what we can see on the flight model with a 4 times powerful laser.

The fluorescence imaging shows that the jacket is affected but not totally removed and that the aramid fibers, supposed to prevent from high temperatures (about 400°C), are not broken.

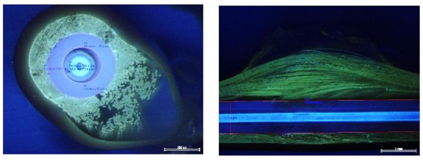
Therefore, the goal of the following studies, in our laboratory was to reproduce strictly the same damage and to evaluate the integrity of the low protecting layers of the fibers.

UV, tomography and DSC in CNES Lab

EADS mentioned a possible incident due to the use of a hot air gun too close to the optical fiber. We performed different tests on a fiber sample and finally reproduced the damage. The tomography and cross-sections images on sample show that, at these temperatures (about 500°C/20seconds), the shape of the sheath is preserved. It means that the optical fiber is still free to move in the sheath. Thanks to the aramid fibers, the excess of heat has been dissipated along the cable. The ePTFE also plays a role in this dissipation.

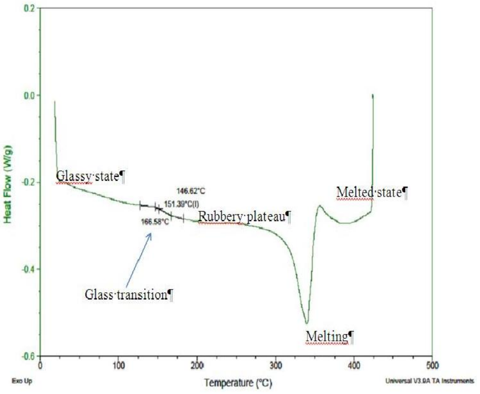


X-ray pictures extracted from tomography videos



Cross-section under UV light

Differential Scanning Calorimetry measurement on the sheath showed that the glass transition temperature at a quite high temperature is the same for the heated and the unheated overall optical cable. In addition, other characterizations have been performed like thermal shocks:10 cycles thermal test (+45°C / -50°C) and 12 hours storage in a 6.10-7 Torr vacuum chamber.



Conclusion

The laser of SWARM "FM1A" still has a nominal performance in orbit presently. Thanks to this analysis, it was decided not to replace the damaged fiber on the satellite. The laser of SWARM ASM FM1A is showing a nominal performance in orbit since the launch at the end of 2013, and we are fully confident for the future. Most of the tests we perform in cleanrooms during assembling and testing phases are mainly "all or nothing" tests. But in addition to more formal or analytical measurements in a laboratory which are time-consuming, they are really helpful to make decisions or to mitigate the risks. At CNES "Laboratories & Expertise" department, thanks to the miniaturization of technologies, we think it is important, in case of failure, to export instruments from the laboratory to the cleanrooms where the satellites are integrated. In addition, this failure analysis study shows that there is an interest to control and choose the lighting conditions and to select the cameras adapted to the spectral range of the sources from UV and IR imaging. We can notice that fluorescence is a technique, among others, that has to be further explored. That is why we are developing a new instrument to analyze the fluorescence of materials from 300 to 700 nm (described in paper 66463).