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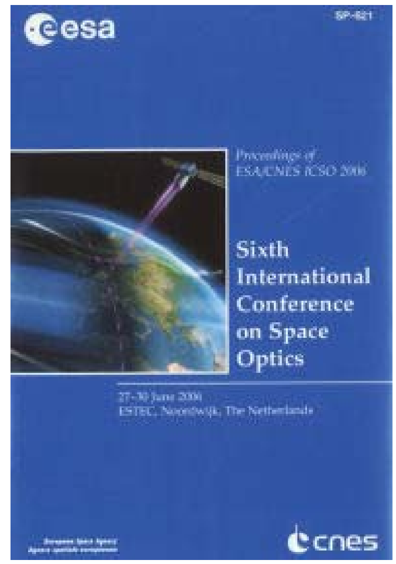

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EVALUATION AND QUALIFICATION OF COMMERCIAL OPTO-ELECTRONIC COMPONENTS FOR THE MOHA SUBSYSTEM IN ESA'S SMOS MISSION

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ABSTRACT

A dedicated evaluation and qualification campaign has been performed on several optical COTS components in order to use them on ESA's SMOS mission. The evaluation phase consisted of a set of critical tests and analyses and led to the selection of the flight lot component. After selection of the components, one lot of each component has been qualified for the SMOS mission.

The overall approach is presented together with a summary of all activities performed. The whole task has been handled in a joint effort between ESA, EADS CASA Espacio (prime contractor), Contraves Space AG (MOHA subsystem), TECNOLOGICA SA (component qualification experts) and the respective manufacturers, each party providing their specific know-how. Test results are presented and the issues discovered and lessons learned are addressed. Special emphasis is given to particular tests for which dedicated setups had to be designed due to the unavailability of standard equipment.

1. INTRODUCTION

SMOS (Soil Moisture and Ocean Salinity) is a satellite designed to observe two environmentally very important variables: soil moisture (SM) over land, and ocean-surface salinity (OS). SMOS will provide information on vegetation water content, biomass, snow cover and ice structure and contribute to research on the cryosphere. Knowledge of the global distribution of soil moisture and ocean salinity with adequate spatial and temporal sampling is expected to significantly improve the forecasting of weather, climate and extreme-event. The SMOS mission consists of an aperture synthesis radiometer with individual antennas connected to the central correlator unit. An optical fibre harness is used to distribute clock signals to the individual antennas and also to transmit the returning data signals back to the correlator unit. Optical transmission had been chosen mainly to comply with requirements of signal phase stability over temperature. The MOHA (MIRAS Optical Harness) subsystem provides this optical link.

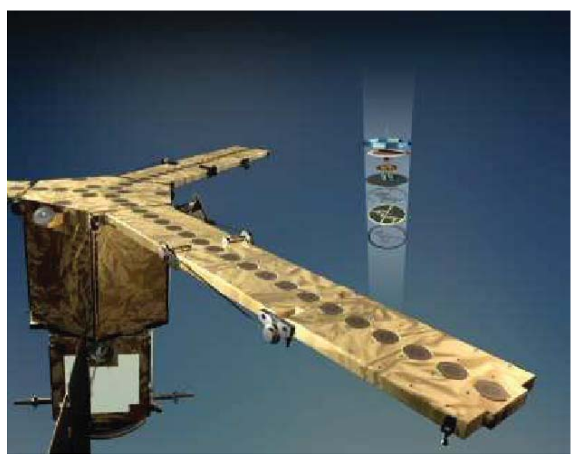

Fig. 1. Artistic vision of the SMOS satellite

2. OPTICAL COTS COMPONENTS USED

As there are hardly any space-qualified components available in the fibre optics industry, a specific

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evaluation and qualification campaign has been performed on several COTS components in parallel.
This included:

- Fibre pigtailed laser transmitter (1310nm)
- Fibre pigtailed optical receivers (1310nm)
- Fibre cable assemblies
- Fibre optic splitter assemblies

In order to limit the qualification effort, the various suppliers were asked to use the same fibre cable (customer supplied) from the same lot for their respective components.

3. EVALUATION PHASE

The evaluation phase was performed in order to reduce the risk of a failure during flight lot qualification with all its implications in terms of cost and schedule. Two possibilities from different manufacurers for each component were subjected to the evaluation process as depicted in Fig. 2.

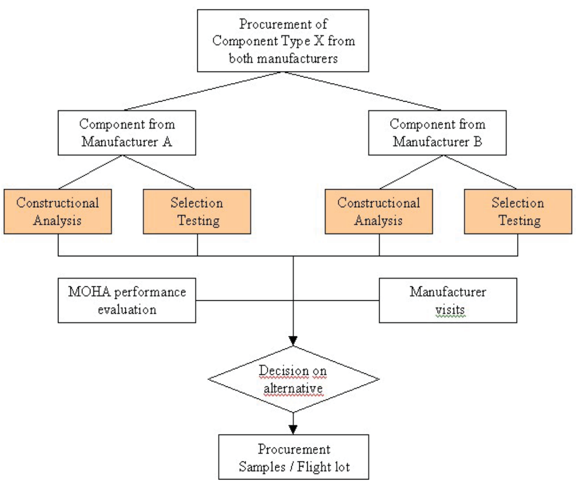

Fig. 2. Evaluation flowchart

On the one hand it consisted of a set of the environmental tests (selection testing) and on the other hand of constructional analysis and manufacturer assessment. For the fibre optic parts subjected to the evaluation phase, the environmental tests considered most critical were:

- vibration (random and sine),
- irradiation (gamma and/or proton depending on technology)
- thermal vacuum cycling

In order to limit the cost it was not feasible to procure and qualify two lots per component in parallel and therefore at the end of the evaluation phase one component (per type) had to be selected for the flight lot (and the respective qualification campaign).

The parts generally performed correctly in environmental testing (although they were tested to far higher levels than specified for, by manufacturers). In the constructional analyses performed some concerns were raised such as weaknesses in packaging or flaws in manufacture. However, the key decision drivers were 'soft' factors like the manufacturers willingness to cooperate in the process or the possibility to procure customized products. Accordingly, the decision on which components to procure for the flight lot was not always straight forward and in delicate cases extra iterations were needed.

4. QUALIFICATION PHASE

The lot procured for the flight model was then subjected to a lot and mission specific qualification campaign. The flow for this qualification is depicted in Figure 3.

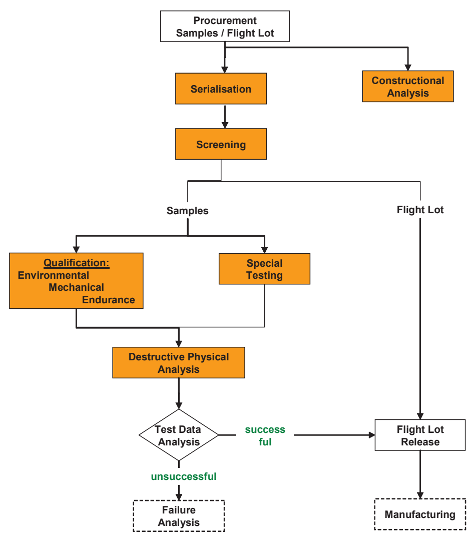

Fig. 3. Qualification flowchart

For each component a dedicated test plan was established. The exact extend of the testing was agreed between all parties involved. As a general rule the test plans were made according to ESCC guidelines and comprised of burn-in /screening made on all parts and on LAT (Lot Acceptance Test) testing on sample basis. The LAT always included

- environmental testing (temperature, vacuum, radiation)

- mechanical testing (vibration, shock, in case of fibre optic cable bending, flexing cable retention)
- endurance testing (temperature life)

The test parameters were either given by the mission requirements or then derived from discussions with the respective manufacturer.

In the subsequent sections this article focuses mainly on tests that required custom made setups or tests in which particular issues were observed.

5. RESULTS AND ISSUES

5.1 Transmitters: Cracks in Tack Welds.

The external visual inspection performed during the construction analysis of the transmitters (ESA) showed cracks in the tack welds from the very beginning. These tack welds were used to fix the TO can inside the outer metal housing that holds the fibre pigtail assembly. Fig. 4 shows these cracks.

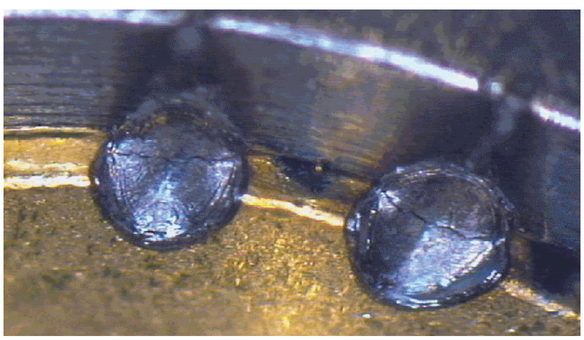

Fig. 4. Cracks in the tack welds

The number of tack welds per device was around 17 sometimes ever higher. The shape and size of the cracks was closely monitored throughout the LAT testing and no change could be observed. Additionally, cross-sections were performed. The results of the test and the inspection of the cross-sections allowed determining that the reliability of the lasers was not reduced due to this defect. The cross section also showed that the shape of the cracks prevents the TO can from moving. The following picture shows a detail of this cross-section.

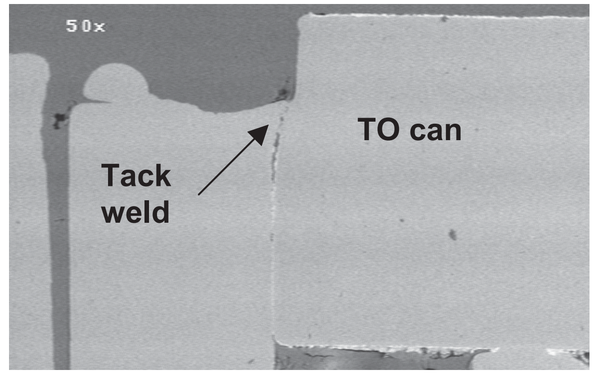

Fig. 5. Cross section of a tack weld crack.

5.2 Transmitters: Humidity Content in TO-can

In the evaluation phase a high humidity content was found inside the hermetic TO-cans of the fibre pigtailed laser transmitters. Humidity poses a reliability concern as it may affect the laser facet. This problem could be overcome only in close cooperation with the manufacturer, who made several changes to his packaging line in order to reduce the humidity content.

5.3 Transmitters: Low Temperature Behaviour

During the qualification campaign a particular behaviour at low temperature was observed: For some transmitters the slope efficiency changed at a certain power level, showing kinks in the power-current curve.

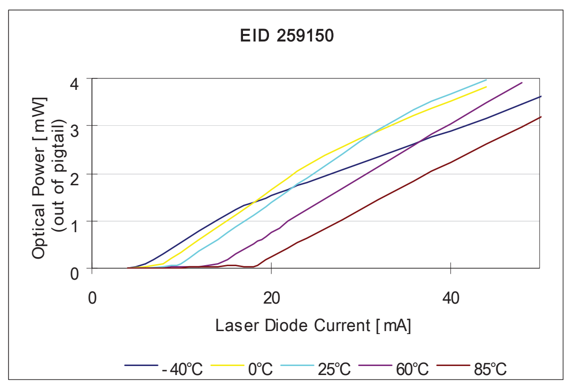

Fig. 6 Kinks in power-current curve

Discussion with the manufacturer led to the conclusion that at low temperatures a second laser mode starts oscillating and only one mode is coupled into the fibre pigtail leading to the kink in the power-current curve.

This effect leads to difficulties in an automatically power controlled system since the monitor photodiode (inside the transmitter housing) would detect the multimode optical power, whereas only a single mode propagates in the fibre, leading to a tracking error of the optical power out of the fibre optic pigtail.

In order to overcome this problem it was decided to screen the complete lot at minimum operating temperature and to single out transmitters with potentially high tracking error.

5.4 Receivers: Weak Bonding

The construction analysis performed by ESA during the evaluation phase, showed weak bonding between the receiver housing and its flange. The analysis already anticipated that this could lead to a reliability problem that could be detected by vibration tests.

The results of the vibration tests during the qualification phase demonstrated this point: In random vibration test one receiver broke loose from its flange (see figure 6).

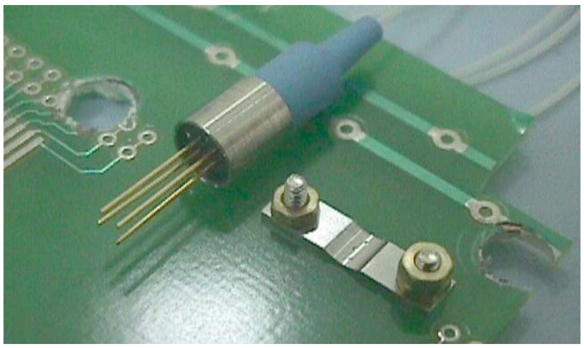

Fig. 7. Receiver vibration failure

In order to prevent these failures, epoxy was used to secure the housings to their flanges. A repetition of the vibration test with these secured components provided good results. Thus, all fibre optic receivers were to be secured in this way to comply with mission requirements.

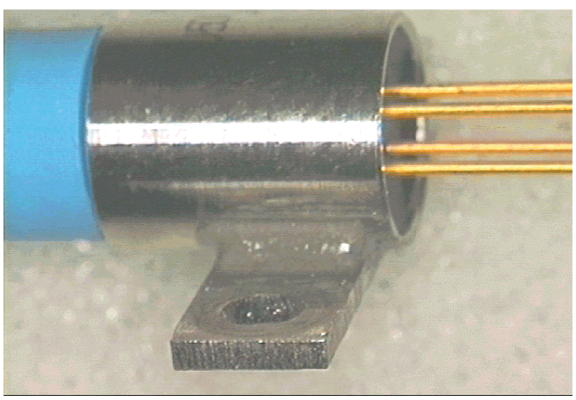

Fig. 8. Epoxy fixing the receiver metal parts.

5.5 Fibre Cable Assemblies: Cleanliness

The evaluation phase showed that the main critical aspect of the fibre cable assemblies is cable design with respect to the applicable temperature range and in particular cleanliness of the fibre optic connectors. The connectors used were of type AVIM. Repeated connectorisation cycles were found to be responsible of metal debris that could influence the optical characteristics of the connections. And thus repeated inspection and cleaning of fibre optic connectors and bulkhead adapters was mandatory not only for the qualification test campaign, but throughout the manufacturing and integration steps for the MOHA subsystem (and its integration onto SMOS).

A mate-demate test of fibre optic AVIM connectors was performed during the project qualification phase. One connector was submitted to a 100 cycles of mate-demate. The attenuation of the connector was measured every 10 cycles. Cleaning was necessary every 10 cycles (with the only exception of the first 10 cycles) as debris from the metal connector was deposited in the internal part of the connector. The tighten force to screw the connector was also increased.

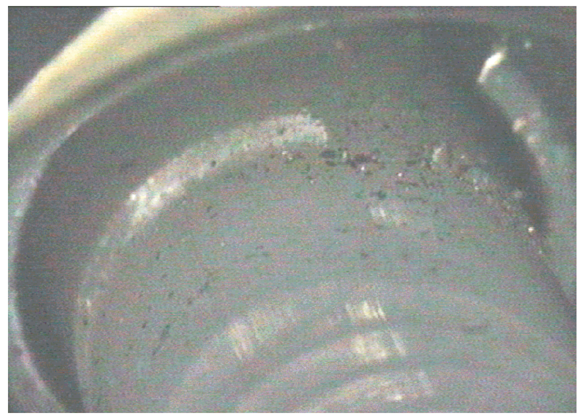

Fig. 9. Internal aspect of the connectors after mate-demate test.

5.6 Fibre Optic Splitters: Cable Shrinkage

The evaluation tests of the splitters showed that the external jacket of the fibre cable shrank during thermal cycling. This led the fibre core to move into the splitter housing. This shrinkage is related to internal stresses in the cable jacket that are released at elevated temperatures and thus lead the jacket to shrink in length. Due to this effect the cable design for the cables subjected to the harshest thermal environment had to be changed and for all cables a preconditioning was introduced prior to connector assembly.

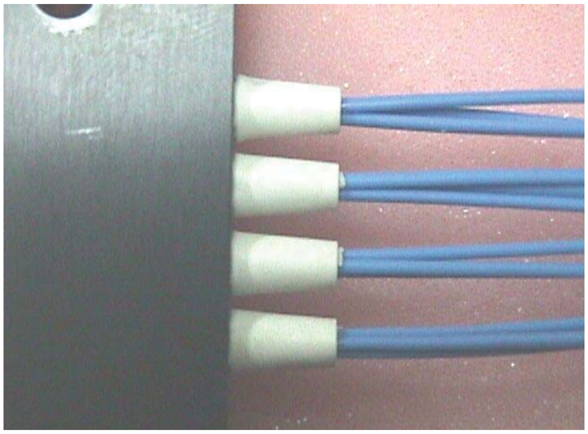

Fig. 10. Splitters output of the fibres

5.7 Fibre Optic Cables: Retention Tests (Torsion, Tension and Compression)

Retention tests (torsion, tension and compression tests) were performed while measuring the optical characteristics of lasers, receivers, fiber cables and fibre optic splitter assemblies. These tests were implemented by fixing the optical connectors to a system that was able to apply and measure forces by using a rotating fixing tool. As an example, the following graph shows the evolution of the attenuation of a fibre cable assembly while tension and torsion were applied. All samples passed the tests**.**

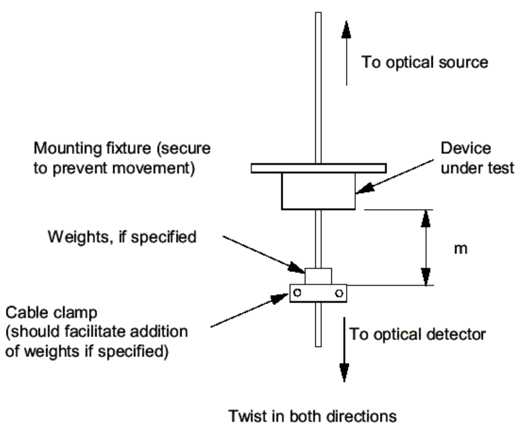

Fig. 11. Set schematic for cable retention test.(fibre cable assembly)

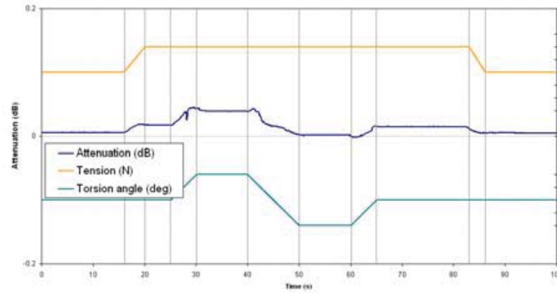

Fig. 12. Attenuation evolution during torsion and tension test (fibre cable assembly)

5.8 Fibre Cable Assemblies: Cold Bend Test

A cold bend test was implemented for checking the behaviour of an optical fibre while it was bended under space conditions. The test was performed at –60ºC using a climatic chamber with a hole. A system with a chain was used to rotate the cylinder where the fibre was placed. The test included ten cycles of bending of a complete turn of the fibre in both directions. Humidity was reduced in two steps. The climatic chamber reduced the humidity while the temperature was over zero degrees. Nitrogen atmosphere was used all the time. The following graph shows an example of the obtained results.

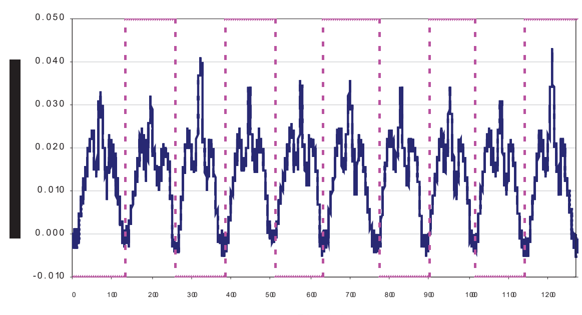

Fig. 13. Evolution of the attenuation of a fibre during cold bend test.

Receiver: Shock Test Failure

A receiver failed after mechanical shock tests. The responsivity decreased to less than 20% of the original value. After several inspections, the failure was found to be related to the presence of a particle located at the end of the fibre placed in the photodiode. A picture of the particle was taken and an EDX material analysis was performed before removing it by means of mechanical methods. The electro-optical measurements after removing the particle demonstrated that the particle was the cause of the failure. The origin of the particle seems to be related to the two polishing planes of the end of the fibre that leave a hole that connects the cavity in the photodiode to the lateral of the fibre. The following pictures show the receiver opened and the particle located exactly at the centre of the fibre. After removal of the particle the receiver was operating normally.

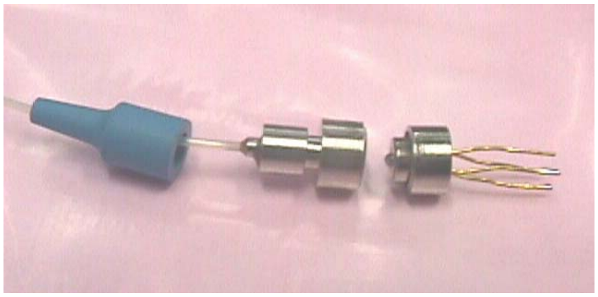

Fig. 14. Receiver opened.

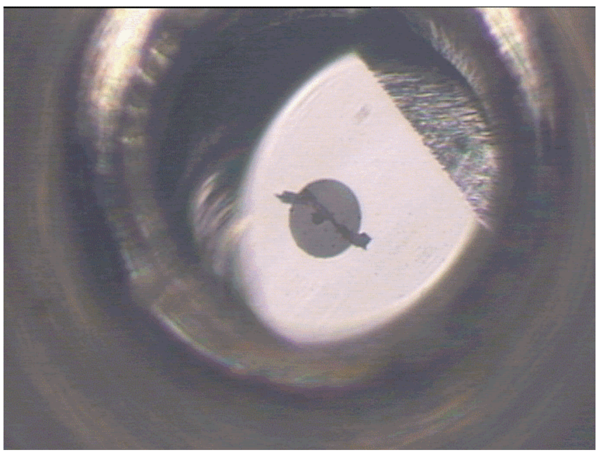

Fig. 15 Particle found on the end of the fibre after opening the receiver.

6. CONCLUSIONS AND LESSONS LEARNED

Small number of optical components are qualified for space applications. This means that more and more COTS components have to be used. A cost effective approach for a lot and mission specific qualification of COTS components has been presented in this paper.

An evaluation phase comprising of a detailed construction analysis and the most critical environmental and/or performance tests is strictly recommended prior to procuring the flight lot. In this early phase several candidates (at least two from different manufacturers) should be available per component type.

In most cases the manufacturer willingness to cooperate in the project was the key decision driver which component to procure.

Be fast. The shown approach is designed to qualify one lot. The fibre optic industry is fast changing and even in the relatively short time between evaluation and qualification, some minor changes in the internal design of some components were observed.

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