

## AVIM AND MINI-AVIM AS FIRST QUALIFIED CONNECTORS FOR SPACE APPLICATION UNDER ESCC STANDARDS

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### I. INTRODUCTION

Following our previous article about Optical fiber connectors for space at the previous ICSO2012 conference[1], we present here optical connector will be qualified using the ESCC system and report on the final qualification of the AVIM and Mini-AVIM.

After an evaluation destined to find the limits for those connectors, values were set for qualification and a formal qualification performed. During that phase, discussion about the definition of the qualified component was raised and the assembled optical connectors were defined as the scope of this qualification.

Lesson learned during this ESA ECI program funded project are presented and should help future user using fiber optic connectors in space application to handle it's qualification and procurement.

### II. ESA ESCC QUALIFICATION OF COMPONENTS

#### A. Background on ESCC system

The ESCC Executive coordinates activities related to the evaluation and qualification of EEE components, technologies and component manufacturers, and issues the appropriate ESA certificates. Companies which have successfully met the requirements are listed on the formal ESCC QPL and QML document (ESCC publication REP005 and REP006 ) which can be accessible on the ESCIES [2] web site.

The requirements for qualification of standard components for space application are given in ESCC Basic Specification 20100 [3].

Following the initial selection of the component/technology, the formal qualification procedure consists mainly in two phases.

#### i. The Component Evaluation including:

- An Evaluation of the Manufacturer (quality system and line audit). The minimum Quality Management System requirements are defined in ESCC 24600 (e.g. control of documents, of process changes, of non-conformances, traceability, role of the ESCC Chief inspector ...)
- An Evaluation Testing phase: during that phase components are extensively characterized and failure mechanisms/margins determined (tested to destruction whenever possible). In addition, a Process Identification Document (PID) for the component to be qualified shall be prepared as described in ESCC Basic Specification 22700.

#### ii. The Qualification Testing phase

The phase is made with components produced, tested and screened strictly according to the Component Detail Specification and PID (usually a different lot/batch than for the evaluation phase). The purpose of the PID is to ensure that a precise reference is established for a component qualified in accordance with the ESCC System. The document enables to control the component's manufacture and ensure that all future components supplied by the Manufacturer will be identical to those for which approval was originally granted.

This reference shall comprise the component's design configuration, materials used for its manufacture, manufacturing processes and controls, and completely define all inspections and tests to be carried out during and after manufacture. The PID shall also provide a standard reference against which any anomalies occurring after qualification approval are examined and resolved.

In brief, an ESCC qualified component is described by:

- Detail Specification for its fit, for, function and performance
- Generic Specification for the in-process, screening and qualification tests and controls
- PID for its manufacture and construction

In the case of departure of any characteristic from the ESCC specification, the Manufacturer shall invoke the Non-Conformance Control System (NCCS) in accordance with ESCC Basic Specification 22800.

A qualification, once established is valid for a maximum of two years from the date of formal certification. Afterwards, the updated PID and maintaining qualification test data shall be provided to the ESCC

Executive, assuming that all the non-conformances have been adequately resolved. The currently listed company in the ESCIES website are the ones with valid certificates.

There is a high level of cooperation between all of the parties involved in an ESCC Qualification process. This close cooperation provides the users of the ESCC system and products with a high level of confidence in the performance, quality and reliability of ESCC products.

In addition to the ESCC QPL, a more extensive list, not limited to European sources, the European Preferred Part List (EPPL) [2], has been established to direct the user towards a limited number of component types, covering all design applications for space use. In addition, the following may also be listed in the EPPL: semiconductor die, semiconductor foundry processes, hybrid assembly processes, ESCC Capability Approvals and ESCC Technology Flow approvals. The aim of this document is to avoid duplication, to achieve cost reduction and to increase procurement effectiveness in a project. The EPPL is issued 3 times a year and is subject to technical review, oversight and maintained by the EPPL Technical Authority (TA) which involves bodies from different space agency, primes and manufacturers.

The EPPL is made up of two parts:

- Part I: components which are fully qualified or evaluated to recognized space standards (e.g. ESCC) giving full or high confidence for space usage.
- Part II: components for which the potential capability to satisfy space application requirements has been demonstrated but which have not yet achieved space qualification.

The components listed in the QPL and QML issued by ESCC (REP 005 and REP 006 respectively), are included by default in EPPL part 1. All the requirements and management of the EPPL are described in a new version of the ESCC specification 12300 issued in S1 2014 [4].

The ECSS space assurance Standard [5] defines the requirements for the procurement of the components and technologies that are intended for use in ESA and other European spacecraft and Space segment hardware. ECSS-Q-ST-60 requires the use of components listed in EPPL part 1, which include the QPL components, as preferred source and with higher priority for usage in Class 1 space project. The Lot acceptance testing which is required for the procurement of non-qualified components, is usually not required for the procurement of QPL components.

This generic exercise of qualification is benefic for European Space projects as the ESCC QPL parts can be procured with confidence, competitive in price and with reduced or no additional testing. The overall recurrent cost, time and engineering effort (parts approved by Declared Component List without Parts Approval Documents) on procurement for every project is therefore reduced. The manufacturers with qualified parts benefit of the ESCC recognition with a positive impact on their sale for ESA projects and for market outside Europe.

#### *B. Qualification status for optical connectors*

The generic used of opto-parts has increased in the past years and therefore the need of having optoelectronic qualified parts has been expressed by the Photonics space community. So far, no opto-parts are listed into the ESCC QPL and only one specification has been published. This ESCC specification 9020 [6] is mainly used by ESA projects to support the qualification testing for the procurement of image sensors.

Due to the recurrent use and flight heritage of the AVIM optical connector [1] and the strong interest for the smaller version Mini-AVIM, the Photonics Working Group expressed the need of having these two parts qualified. Therefore, an activity targeting the ESCC evaluation and qualification of the AVIM and Mini-AVIM from Diamond has been initiated in the frame of the European Component Initiative (ECI) program. As no ESCC specification was existing for the evaluation and qualification of optical connectors, it has been decided to develop these specifications in the frame of the activity as a pilot case. Experts from the Photonics Working Group have been involved in the review and technical approval of the specifications through the activity.

The activity has been successfully completed end of 2013 with the Final presentation held at ESTEC. The deliverables including all the Technical Notes and a draft proposition for the ESCC Generic, Basic and Detail specifications for the AVIM and Mini-AVIM have been provided to ESA. The technical results for the testing have been approved by ESA and meet the requirements for having the parts listed into the QPL and consequently in EPPL part 1.

However, before having the parts proposed for inclusion into QPL, the Specifications need to be available in the ESCC format and approved by the Policy Standard Working Group (PSWG). The technical content of

the specifications have been agreed by the Photonics Working Group and will be proposed for endorsement by the PSWG meeting to be held end of 2014. After publication of the ESCC specification, the parts will be proposed and confidently listed into QPL in February 2015 and consequently in EPPL part 1.

In case the specifications are not published by the end of 2014, the AVIM and mini-AVIM will be proposed to be listed directly into EPPL based on the evaluation and qualification test reports and detail specifications.

By having the AVIM and mini-AVIM listed into the QPL, Diamond will make sure to maintain its quality system and PID updated and inform ESA on any Non Conformances related to these products. Diamond will perform periodic maintenance of qualification every two years to maintain valid the ESCC certificates. Diamond will take opportunity of these maintenance of qualification to use test vehicles including different type of cables, fibers and adapters in order to expand the range of qualified variants.

Space customers will be able to procure, according to the respective ESCC detail specification, the AVIM and mini-AVIM assembly marked with ESCC logo. For space projects following procurement according to the ECSS-Q-ST-60, no additional or reduced testing will be necessary on the procured parts.

### III. AVIM AND MINI-AVIM QUALIFICATION

As explained briefly in the introduction, the components qualified are the assembled connector set using a specific cable and a specific fiber. The qualification covers the connector itself and the assembly process for this precise fiber/cable configuration.

To extend this work to other fibers, similarity between fibers is discussed and delta qualification already proposed.

The final specifications are found in the datasheet of the AVIM[7] and Mini-AVIM[8] as published on our website and upon availability of the QPL certification, small changes will be made to reference those standards.

### IV. FAQ about qualification status

#### A. *What is qualified?*

The qualified parts are the connectors (AVIM and Mini-AVIM) assembled with a 1mm OD PEEK tubing and a Fujikura PM 1550nm optical fiber with 400um dual acrylate coating.

#### B. *What requires delta qualification*

##### iii. Fiber

Changing the fiber requires a fiber qualification. No standard exist at this point and radiation resistance for the application intended as well as the coating definition must be defined by the mission.

The qualified technology can be adapted for fibers with cladding from 80um to 500um and for SM, PM, PZ and MM fiber structure. Other structure can be adapted (double clad, polycrystal fibers, multi-core fibers,...) as special development.

##### iv. Cable

The cable replacement from PEEK must be re-qualified (resistance in temperature, assembly feasibility,...). This again depends on the mission.

AVIM assembly can be adapted from 900um to 3.5mm cable structure standard, for other configuration on request. Cable assemblies have not been qualified, but experience exists for the Gore Flexlite 1.2mm cable construction.

For the Mini-AVIM, only the cable from 900um to 1.2mm are standard to the structure and can be adapted too.

#### C. *What is not qualified*

Variation in component material, bare fibers application,...

### V. PROCUREMENT

A difference must be made between qualified components procurement and non-qualified component procurement.

#### A. *Qualified components*

Patchcords: Variation is only length.

Mating adapter: No variation within one type.

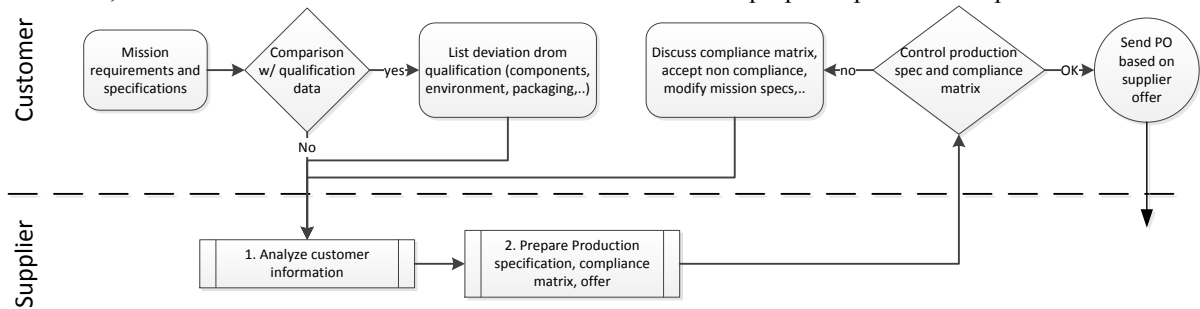
For the AVIM and Mini-AVIM the part number for the mating adapter are given in the respective Part Number Lists [9], [10] as published on our website, for the Patchcords, a configuration code is explain on our datasheet to allow ordered qualified Patchcords [7][8].

Upon release of the ESCC specification and certification in the QPL list, those numbers will be found there too.

In the meantime, those products are released with a Product Specification Document related to our published Qualification Test Report [11][12]

### B. Non-qualified components

This is still almost the majority of components ordered today, with the increase of configuration qualified in the future, this should be easier. You'll find below a flowchart of our proposed procurement process.



We advise not to consider a patchcord or hybrid patchcord as an of-the-shelf component, because it still must be specified, documented and produced individually.

A Product Specification Document (PSD) will be written by Diamond along with a compliance matrix, in there, Diamond will write the status of each item requested in the mission specification with comments. The responsibility of the correspondence of the offered non-qualified component to the mission spec is with the customer who has full understanding of the mission. Normally several back and forth are necessary and Diamond tries to support and advise the customer to their best.

## VI. LESSON LEARNED

During this long program, a study with an evaluation, followed by a qualification and the redaction of new standard was done. Of course not everything went without trouble and a few lesson were sometimes learned in the hard way. Here a few of them are describe with the hope it will help the community to be careful and not to repeat the same mistake and/or to change the approach for a superior return.

### A. Testing pigtail and testing Patchcords

During the beginning of the project where the aim was more to qualify the connector itself, pigtails were tested. By pigtail we intend that only one connection of two pigtail and a mating adapter was tested in climatic chamber, as seen below.

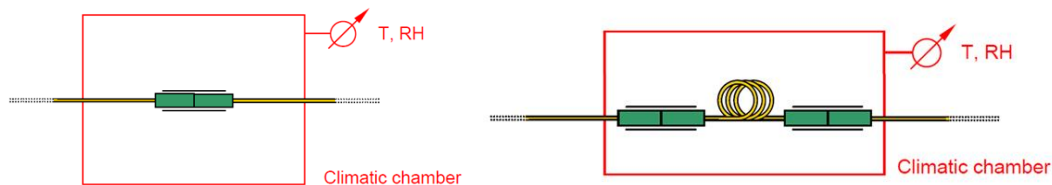


fig. 1 Pigtail connection (left) versus Patchcord connection (right)

This allow to understand what happens on the connector side, more independently than the cable. But as on a patchcord, the cable has a large influence on final specification, the patchcord connection was used in the qualification.

Both these two configuration are necessary, but the patchcord connection is the only one allowing the full qualification of a complete patchcord submitted to the environment.

### B. Quality process control for epoxy: epoxy sample

During our program, the epoxy used was wrong. In order to find this, we had to analyze the polymerized glue present in a connector, which is not only a costly analysis, but a difficult too due to the small amount used.

This analysis could be performed, but to avoid this issue, we decided to realize for each use of epoxy in a Space Grade order one sample of the glue from the same batch which is then polymerize with the same process and kept with the travel cards of each order.

This issue was extremely difficult to find and caused long delay until the problem was found during the project.

## VII. CONCLUSION

The completion of this pilot case for defining the proper qualification procedure for optical fiber connection took longer than expected but helped progress the ease of use of optical connector for space application. From a manufacturer's point of view, this pilot case allowed us to define and implement a 40m2 clean room, new quality procedures and processes and change some mentality toward a different manufacturing than mass market telecom product.

We are very thankful to all the help that came from the community and ESTEC support, as well for the understanding of all the stakeholder. Quality is a non-ending thing and Diamond will thrive to support the user community for these application with the 30plus year experience and the assurance of a vertically integrated supplier able to control/modify each individual component and process.

## VIII. REFERENCES

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- [6] ESCC 9020, Photosensitive charge coupled devices and CMOS imaging sensors with hermetic and non-hermetic packages.
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