SLOVENSKI STANDARD
oSIST prEN 4533-003:2024

01-junij-2024

Aeronavtika - Sistemi iz optičnih vlaken - Priročnik - 003. del: Postopki za izdelavo in namestitev vezalnega pasovja

Aerospace series - Fibre optic systems - Handbook - Part 003: Looming and installation practices

Luft- und Raumfahrt - Faseroptische Systeme - Handbuch - Teil 003: Verfahren zur Fertigung und Installation von Leitungsbündeln

Série aérospatiale - Systèmes des fibres optiques - Manuel d'utilisation - Partie 003 : Règles de l'art pour la fabrication et l'installation des harnais

Ta slovenski standard je istoveten z: **prEN 4533-003**

ICS:

33.180.01	Sistemi z optičnimi vlakni na splošno	Fibre optic systems in general
49.060	Letalska in vesoljska električna oprema in sistemi	Aerospace electric equipment and systems

oSIST prEN 4533-003:2024 **en,fr,de**

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

DRAFT
prEN 4533-003

March 2024

ICS 49.060

Will supersede EN 4533-003:2017

English Version

Aerospace series - Fibre optic systems - Handbook - Part 003: Looming and installation practices

Série aérospatiale - Systèmes des fibres optiques - Manuel d'utilisation - Partie 003 : Règles de l'art pour la fabrication et l'installation des harnais

Luft- und Raumfahrt - Faseroptische Systeme - Handbuch - Teil 003: Verfahren zur Fertigung und Installation von Leitungsbündeln

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee ASD-STAN.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom.

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. prEN 4533-003:2024 E

Contents

Page

European foreword

This document (prEN 4533-003:2024) has been prepared by ASD-STAN.

After enquiries and votes carried out in accordance with the rules of this Association, this document has received the approval of the National Associations and the Official Services of the member countries of ASD-STAN, prior to its presentation to CEN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 4533-003:2017.

The main changes with respect to the previous edition are as follows:

— update of the document to remove trademarks.

Introduction

a) The handbook

This handbook aims to provide general guidance for experts and non-experts alike in the area of designing, installing, and supporting fibre-optic systems on aircraft. Where appropriate more detailed sources of information are referenced throughout the text.

It is arranged in 4 parts, which reflect key aspects of an optical harness life cycle, namely:

- Part 001: Termination methods and tools;
- Part 002: Test and measurement;
- Part 003: Looming and installation practices;
- Part 004: Repair, maintenance, cleaning and inspection.

b) Background

It is widely accepted in the aerospace industry that photonic technology significant advantages over conventional electrical hardware. These include massive signal bandwidth capacity, electrical safety, and immunity of passive fibre-optic components to the problems associated with electromagnetic interference (EMI). Significant weight savings can also be realized in comparison to electrical harnesses which may require heavy screening. To date, the EMI issue has been the critical driver for airborne fibre-optic communications systems because of the growing use of non-metallic aerostructures. However, future avionic requirements are driving bandwidth specifications from 10s of Mbits/s into the multi-Gbits/s regime in some cases, i.e. beyond the limits of electrical interconnect technology. The properties of photonic technology can potentially be exploited to advantage in many avionic applications, such as video/sensor multiplexing, flight control signalling, electronic warfare, and entertainment systems, as well as sensor for monitoring aerostructure.

The basic optical interconnect fabric or 'optical harness' is the key enabler for the successful introduction of optical technology onto commercial and military aircraft. Compared to the mature telecommunications applications, an aircraft fibre-optic system needs to operate in a hostile environment (e.g. temperature extremes, humidity, vibration, and contamination) and accommodate additional physical restrictions imposed by the airframe (e.g. harness attachments, tight bend radii requirements, and bulkhead connections). Until recently, optical harnessing technology and associated practices were insufficiently developed to be applied without large safety margins. In addition, the international standards did not adequately cover many aspects of the life cycle. The lack of accepted standards thus lead to airframe specific hardware and support. These factors collectively carried a significant cost penalty (procurement and through-life costs), that often made an optical harness less competitive than an electrical equivalent. This situation is changing with the adoption of more standardized (telecoms type) fibre types in aerospace cables and the availability of more ruggedized COTS components. These improved developments have been possible due to significant research collaboration between component and equipment manufacturers as well as the end use airframers.

1 Scope

This handbook considers the best practices during initial design and how the practices chosen affect through life support of the installation. Looming and installation practices are a critical aspect of any aircraft electrical/avionics installation. In order to provide a reliable and efficient system, it is important that the fibre optic installation is designed for reliability and maintainability.

This document provides technical advice and assistance to designers and engineers on the incorporation of fibre optic harnesses into an airframe, while, wherever possible, maintaining maximum compliance with current aircraft electrical harness procedures.

All topics that are related to the installation of optical cables are addressed in EN 3197.

These rules are applicable for fibre optic cables and connectors defined by EN specifications.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp/
- IEC Electropedia: available at https://www.electropedia.org/

4 Initial design considerations

4.1 General

Wherever possible the installation of fibre optic links and bundles should aim to mirror that of copper systems and comply as much as possible with current general aircraft electrical harness procedures. There are numerous installation specifications detailing the requirements for the routing of copper-based harnesses, however they are very similar in content, therefore fibre optic harness routing will have to fulfil the following criteria:

a) accessibility for inspection and maintenance;

b) prevent or minimize the risk of damage from:

  - chafing, scraping or abrasion,
  - use as handholds or as support for personal equipment,
  - damage by personnel moving within the aircraft,
  - stowage or movement of cargo,
  - battery electrolytes and fumes,
  - stones, ice, mud and burst tyre debris in landing gear bays,
  - combat damage (to the maximum extent practicable),

- loose or moving parts,
- moisture and fluids,
- localized high temperatures,
- frequent mating and de-mating of connectors,
- exposure to high temperature/high vibration areas.

Copper installations are prone to electrical interference and their use is restricted in “volatile” zones. Fibre optic cables are immune to electrical interference and are ideally suited for use in, or routing through “volatile” zones. Examples of areas that fibre optic harnesses may provide a better solution over copper include:

c) areas where there are high levels of electrical field;

d) areas where electric fields need to be kept to a minimum, e.g. compass deviation;

e) routing through and close to fuel tanks;

f) close proximity to electrically initiated explosive devices (EIEDs) and their systems.

During the design phase of a fibre optic installation routing considerations need to be addressed when determining the optimum routing, these include:

g) system criticality;

h) harness accessibility, improves on-aircraft repair and maintenance, but should not degrade system protection;

i) system segregation and redundancy, maximization of damage limitation;

j) accessibility of connectors;

k) system and component repair and maintenance issues (it is noted that design of common harness lengths on an aircraft may improve the supportability (common spares inventory) if repairs are required);

l) introduction of dormant fibre in harnesses and/or extra fibre lengths may reduce on-aircraft repair times.

4.2 System design considerations

4.2.1 Introduction

In the design of a fibre optic harness, the link topology and the available routing path on the platform will dictate the physical length of the harness and any required branching of the assembly.

If the fibre optic installation is to be installed on an existing platform, then possible routing paths may be restricted (due to existing infrastructure and equipment). However, if the platform is a new build, then there may be more freedom to design the routing path.

It is noted that fibre optic design software has been developed to assist in the layout of fibre optic harnessing. This can be used to model different paths and also calculate insertion loss of the link, depending on the path route. A small number of commercial packages are believed to be available.

These can also predict losses associated with installation bends of the optical fibre and connector misalignment.

It is further noted that modern fibre optical cable designs are utilizing bend tolerant optical fibres and a number of aerospace designs are in existence. These exhibit lower losses when bent to a small radius. Whilst this could allow tighter installation bends to be designed, it needs to be emphasized that the strength of the optical fibre still needs to be respected. Generally tighter bends will increase the strain on the fibre and may reduce lifetime (particularly if there are any defects in the glass). It is therefore generally advisable to ensure typical minimum bend radius limits for aerospace optical fibre cables according to the product standard.

4.2.2 Interconnects

Fibre optic connectors (interconnects) will be required to connect the fibre optic harness to end equipment or to other harness sections on the airframe. It is noted that harnesses may require multi-way connectors (with multiple optical contacts or termini) or single-way connectors depending on the specific design of the harness. This will in turn affect the management of the optical cable leading to that connector and any back shell design.

Careful attention should be made to the number and placement of interconnects in the fibre optic links. The final choice and location of the interconnect needs to take into account the required performance, reliability and maintenance elements of the system. These aspects often conflict with each other in system design and so some trade-off should be performed at the design stage.

Of primary importance is that the fibre optic interconnects and components do not introduce a loss that exceeds the power budget of the system. Provided that sufficient power budget is available, the use of appropriately positioned production breaks can improve the maintainability of the system. For example, in areas of high maintenance activity where there is an increased likelihood of damage, the use of additional interconnects with short fibre optic links will facilitate a quick and simple replacement of a damaged link. In turn this capability has to be traded against the possibility that the additional interconnects may increase the insertion loss of the links reducing the reliability of the system. Experience has shown that failures at or near to the interconnect are not an uncommon failure mode, particularly where loads placed on the links are easily transferred to the interconnect assembly and associated accessories. Careful placement of the interconnect and the correct use of appropriate harness tie-down mechanisms will reduce the likelihood of this type of failure.

Some systems (particularly single-mode systems with laser sources) may also be sensitive to reflections propagating back to the source. Additional connectors added to improve maintainability may significantly increase the total amount of reflection depending on the connector design. Where sensitivity to back reflection exists, low reflection connectors such as UPC or APC types may need to be considered in the design.

In summary the introduction of additional interconnects should be considered if the attendant increase in insertion loss and back reflection can be accommodated by the system, and the additional interconnects improve maintainability without causing impact on the reliability of the system.

It is noted that connectors and tight bends will generally introduce the largest losses into an optical fibre harness. The material attenuation of the glass fibre will be small over the relatively short harness lengths of an aircraft. In addition to the losses of the cable and connectors in the system it is generally advisable to allow a 3 dB margin in the harness insertion loss to allow for lifetime ageing of the installation. This should also be factored into any system design calculations.

4.2.3 Maintainability strategy

4.2.3.1 General

The design of harness/routing is completely linked with the maintainability strategy. In phase with this strategy, the harness/routing design shall take into account the constraints depending on the choice between:

- the use of splice as repair solution;
- the use of dormant/spare fibres; or
- the replacement as unique repair solution.

4.2.3.2 Splice

Splices present many benefits such as no limitation regarding mechanical and environmental properties when they are properly protected, very low impact on the optical link budget (the losses introduced by the repair have to be taken into consideration, according to the repair type, e.g. mechanical vs. protected fusion splice), and it can be considered as a permanent repair in certain cases.

The main drawback is that it is necessary to access to the fibre optic cable under repair.

4.2.3.3 Dormant/spare fibre

Dormant/spare fibre can be utilized in a fibre optic application installation without excessively diminishing the weight savings attained by using fibre optic cable links. However, the introduction of additional cables links will inevitably increase initial cost and system complexity, together with the additional problems of cable fibre optic link connector end/ferrule protection and stowage. In addition, any spare or redundant fibres links would be subject to the same or similar environmental conditions as the ‘live’ fibre link it is duplicating.

Deciding on the level of redundancy and depth required, should be based on a number of factors, these include:

- careful consideration would have to be taken into account during the design phase to ascertain the depth of spare/dormant fibres required against weight and space envelope restrictions and limitations;
- the introduction of spares into any system would almost certainly have a knock-on effect on cost. In the case of single way connector systems, the cost would be exacerbated due to the increased number of connectors introduced, together with additional Line Replacement Items (LRI), fixed connectors and additional fibre. With the increased use of multi-way connectors in airborne fibre optic applications the introduction of redundant fibres is simplified but once again the overall system cost is increased. However, this is balanced against ease of maintenance and potential cost of ownership savings;
- repair of systems can be improved with the incorporation of dormant fibre, depending on the system damage sustained. The ability to transpose damaged fibres with ‘spare’ fibres, negating the need to remove and replace harnesses may prove beneficial; however, the question raised is “how many spare fibres do you include in each harness?”

Inclusion of additional spare/redundant fibre optic links provides a system capability that will allow continued operation even if damage has been sustained, or a failure to an element of that system has occurred.