

**UNIVERSITY OF WEST BOHEMIA
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF TECHNOLOGIES AND MEASUREMENT**

MASTER THESIS

**The process of creating of Fire properties report;
optimization using 3D construction data**

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Jméno a příjmení: **Bc. Iryna KUDRYNSKA**
Osobní číslo: **E18N0001P**
Studijní program: **N2612 Elektrotechnika a informatika**
Studijní obor: **Komerční elektrotechnika**
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Zásady pro vypracování

Vylepšení metodiky tvorby fireproperties reportu za pomoci 3D dat namísto současného použití ERP/LN

1. Vypracujte návrh úpravy 3D dat pro umožnění tvorby fireproperties reportu za použití 3D dat.
2. Zajistěte klíčové změny 3D systému ve firmě Safran Cabin CZ s.r.o. a vyhodnoťte potřebné technické změny pro umožnění automatické tvorby fireproperties reportu.
3. Vypracujte potřebné dokumentace a technologické postupy tvorby 3D dat pro umožnění tvorby fireproperties reportu se zaměřením na elektroinstalaci a systémy.
4. Proveďte technicko-ekonomické zhodnocení.



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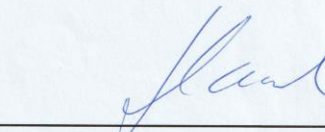
1. JAR Part 25 Change 12, Airworthiness Standards: Large Aeroplanes (for A319 / A320 / A321)
2. JAR Part 25 Change 14, Airworthiness Standards: Large Aeroplanes (for A318)
3. FAA PS-ANM-25.853-01-R2, dated July 3, 2013, Flammability Testing of Interior Materials

Vedoucí diplomové práce: **Ing. et Ing. Petr Kašpar, Ph.D.**
Katedra technologií a měření

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Prof. Ing. Zdeněk Peroutka, Ph.D.
děkan




Doc. Ing. Aleš Hamáček, Ph.D.
vedoucí katedry

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Abstract

The master thesis presents the proposition and implementation of 3D data modification to enable automatic creation of Fire properties report.

The master thesis is divided into the theoretical and practical part. In the theoretical part, the Safran Cabin CZ s.r.o. field of activity and necessary documentation such as aviation certification regulations are described. Further, the technological procedure to enable the automatic creation of Fire properties report using 3D data is analyzed and upgrade of 3D system for Fire Properties report creation was proposed. The practical part contains the creation of the 3D model of LED light, including a brief description of the technologies used and also a technical and economic evaluation of the implementation of technical changes to the 3D system.

Key Words

Galley, stowage, Fire Properties report, 3D system, SOLIDWORKS, electrical wires

Abstrakt

Tato diplomová práce se zabývá návrhem a implementací úpravy 3D dat pro umožnění automatické tvorby Fire Properties reportu.

Diplomová práce je rozdělena na teoretickou a praktickou část. V teoretické části jsou analyzovány obor činnosti firmy Safran Cabin CZ s.r.o. a potřebné dokumentace, jako letecké předpisy. Dále je analyzován technologický postup umožňující automatické vytváření Fire Properties reportu za použití 3D dat a byla navržena aktualizace 3D systému pro vytvoření Fire Properties reportu. Praktická část obsahuje návrh samotného 3D modelu LED svítidla, stručný popis použitých technologií a také technicko-ekonomické zhodnocení implementace technické změny do 3D systému.

Klíčová slova

Galley, stowage, Fire Properties report, 3D systém, SOLIDWORKS, elektrické vodiče

Declaration

I hereby declare that this master thesis is completely my own work and that I used only the cited sources.

I further declare that all software used in solving this thesis is legal.

.....
Signature

Pilsen 16.06.2020

Iryna Kudrynska

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I would like to acknowledge Ing. et Ing. Petr Kašpar, Ph.D. of Faculty of Electrical Engineering at the University of West Bohemia and I am gratefully indebted for his valuable comments on this thesis. I would also like to thank to my supervisor, Jan Beran, for his guidance through each stage of the process.

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Introduction

The presented work is focused on the improving of Fire Properties report creation methodology with the usage of 3D data instead of current use of ERP LN System database.

Certification is one of the most important thing in aircraft industry. The first chapter of the master thesis presents the company Safran Cabin CZ s.r.o. and its field of activity. This chapter also explains basic concepts that are relevant to the work, such as SA ACP project of Airbus, which considers design and deliveries of galleys and stowages for the A320 family of aircraft. The second chapter describes aviation regulation authorities, aviation certification, fire properties qualification and its documentation that describes airworthiness standards for aircraft and ensure the safety of aircraft designs through the certification processes.

The third chapter is focused on the issues of creating a Fire properties report, such as necessary inputs, disadvantages of the current 3D system and determination of needed technical changes to 3D system to allow automatic creation of Fire properties reports, which should be implemented. This chapter represents brief description of the technologies used for improving of Fire Properties report creation methodology and steps for its realization.

The next chapter is focused on practical part, where the 3D model of aircraft LED light and its Design Table are created in SOLIDWORKS software. The creation of the table with data about the 3D model in Microsoft Excel, connection of this table with Fire properties report and the creation of Fire Properties report for 3D model are described. This chapter also presents the description of used technological procedure to enable automatic creation of Fire properties report using 3D data that has a big advantage as the qualification can be done earlier in project timeline.

The last chapter describes the technical and economic evaluation of the implementation of technical changes using the 3D system with the help of five criteria from technical and economic aspect and weight factor. The calculation of the spent time for creation of Fire Properties report before and after changes and cost of making technical changes is performed. This chapter also presents the scope for improvements, total cost of working hours and software price.

List of symbols and abbreviations

SA ACP The Single Aisle Advanced Customization Policy

SFE Supplier Furnished Equipment

BFE Buyer Furnished Equipment

BOM Bill of materials

SPS Standard production specification

FAA The Federal Aviation Administration

ICAO The International Civil Aviation Organization

JAR The Joint Aviation Requirements

EASA European Union Aviation Safety Agency

FP Fire Properties

CIB Certification information bulletin

FP Final Assembly

PDM Product Data Management

CAD..... Computer-aided design

ERP Enterprise resource planning

WF Weight Factor

1 Introduction of company Safran Cabin, history, present state and basic information about the company. Basic concepts that are relevant to the work

1.1 History of the company

The historical combination of Driessen and Sell GmbH companies today is Safran Cabin. This Galley Division of Safran Cabin company invented the modern galley as we know it today. [1]

The original company was initially founded by Gerard Driessen as a plumbing company in 1938. The company entered the aircraft industry in 1946 with glass stands and ovens. In the 1980s, the company was already supplying its products to aircraft manufacturers such as Boeing and Airbus. The company started to operate in the Czech Republic since 2001, when the first production hall was built in Pilsen. Driessen became a part of the French company Zodiac Aerospace since 2008, providing services and products for aircraft interiors, aviation safety, aircraft systems and technologies. [2]

In February 2018, Safran took control of Zodiac Aerospace, what significantly expanded its aircraft equipment activities. Zodiac Aerospace's former activities are now the focus of three new companies within the Group: Safran Aerosystems, Safran Cabin and Safran Seats. [3]

Pilsen plant became a part of the global development of aeronautical innovations thanks to being a part of a strong international group. To official change of the name of Zodiac Aerospace in Pilsen to Safran Cabin CZ s.r.o. occurred on 4 March 2019. [2]

1.2 Basic information about the Safran Group

Safran is a global high-technology group, operating in the aviation (equipment, propulsion and interiors), defense and space industries. [4] The company is headquartered in Huntington Beach in Southern California, USA. The company also employs more than 95,000 people worldwide, in America, Europe, Canada, Brazil, Singapore and Thailand. All the employees

across the globe serve virtually all the airlines, aircraft leasing companies and airframe manufacturers worldwide. [3] The brand logo of Safran Cabin company is shown in the *Fig. 1.1*.



Fig. 1.1 Label of Safran Cabin [4]

Safran companies count on proven quality management systems reflecting the top standards in each of their businesses, including engineering compliance certification and accreditation by recognized aviation authorities (EASA, FAA, etc.).

Safran Cabin provides all elements of Commercial, Regional and Business Jet cabin interior. It offers the overhead bins, lavatories and galleys, crew rests and cargo containers, that can be made as independent products or as a fully integrated cabin.

Mission of company Safran Cabin is to design, manufacture, certify and support the world's most innovative aircraft cabin interiors, providing airlines and other customers with distinctive aircraft branding, and their passengers with a safe, comfortable and enjoyable flying experience. [4]

1.3 Current status of Safran Cabin CZ Pilsen

The Pilsen division is the most efficient unit of the company in the whole of Europe. The Pilsen plant employs more than 1,000 people and continues to grow. [2]

Safran Cabin CZ s.r.o. is an exclusive supplier to Airbus company, which is one of the world's largest civil aircraft manufacturers. Airbus is a leader in designing, manufacturing and delivering aerospace products, services and solutions to customers on a global scale. [5]

In Pilsen galleys and stowages are designed and produced mainly for the A320 aircraft group according to special Advanced Customization Policy (ACP) project. The A330 Lower Deck Mobile Crew Rest (LDMCR) are also manufactured in Pilsen. [1] The orders for Airbus are secured for several years ahead. [2] Example of the manufactured stowages and one of galleys are shown in the *Fig. 1.2*.



Fig. 1.2 A galley and a stowage [1]

The company headquarters is located in Pilsen at Borská pole. Safran Cabin CZ plant consists of the production department, the engineering department (Core Engineering, Project Engineering, Sales Engineering, Certification, Project Engineering, Systems), as well as the Program Management Department, which are constantly growing and modernizing. One of the Safran Cabin CZ s.r.o. buildings in Pilsen is shown in the *Fig. 1.3*.



Fig. 1.3 One of the Safran Cabin CZ s.r.o. buildings in Pilsen [2]

The new offices are fully air-conditioned, equipped with high-quality ergonomic seating and thanks to their original design have been included in the national competition Art of Space Awards (Zasedačka roku) 2017. For the company Safran in Pilsen the design of the walls and

spaces with an aviation theme was elaborated. [2] Reception and engineering department premises are shown in the *Fig. 1.4*.

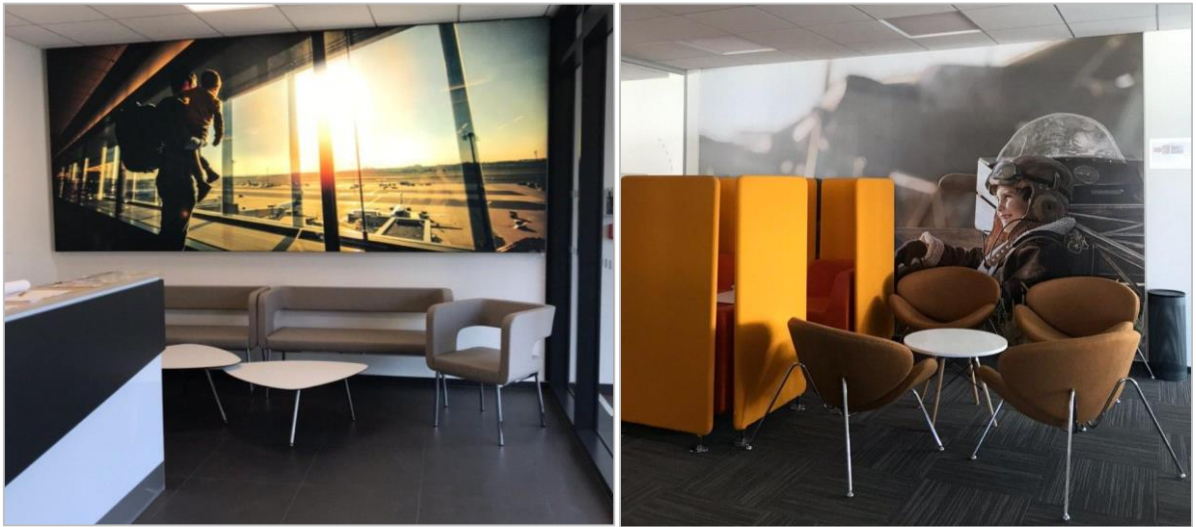


Fig. 1.4 Safran Cabin CZ premises

Production department performs manufacturing such as panel's production, routing, bonding, decor, subassembly, final assembly and testing. Safran Cabin CZ also carry out aftermarket support including repair stations, spare manufacturing and product support. [4]

Currently, Safran Cabin employs engineers and professionals from around the world, as well as students of the University of West Bohemia in Pilsen. Moreover, the company started the partnership with universities such as Czech Technical University in Prague and Brno University of technology. [4]

Investments in innovation and technological advancement are of key importance for the company, so the greatest emphasis is placed on training, expertise and top standards. [2]

1.4 Basic concepts that are relevant to the work

The Pilsen plant produces mainly galleys and stowages for ACP concept. [2] The Single Aisle Advanced Customization Policy (SA ACP) project is a project of Airbus, which considers design and deliveries of galleys and stowages for the A320 family of aircraft. [6] A single-aisle (SA) aircraft is a narrow-body airliner arranged with one aisle. [7]

Galley is a kitchen on board an aircraft, usually arranged in a typical style shown in the *Fig. 1.5*. It includes longitudinal units and ceiling cabinets, which makes the use of the usually limited fuselage space efficient. [8]



Fig. 1.5 Galley type G1 [1]

Stowage is a monument built into the fuselage of an aircraft for stowing luggage for providing a comfortable and safe flight for passengers shown in the *Fig. 1.6*. It is a safety critical element of aircraft design, as unsecured luggage presents a huge risk to the safety of passengers and cabin crew during periods of turbulence. [9]



Fig. 1.6 Stowage [1]

Galleys and stowages in all A320 Family aircraft are SFE (Seller Furnished Equipment) with a wide range of choice of options in line with the Airbus catalogues. [10]

Seller Furnished Equipment (SFE) is equipment selected by the manufacturer, the aircraft supplier, which presents long-term visibility and self-financing of development costs in case of selection. Buyer Furnished Equipment (BFE) is equipment selected by the buyer of the aircraft, airline or leasing company, which presents short cycles, high level of customization. [11]

The SFE galley and stowage are provided with a decor material in the basic colors of the entrance areas. The cabin facing decors are customizable to meet the color arrangement of the cabin. [10]

Each galley and stowage have its own Airbus code. The galley part number is typically 601XXX-YYYY, where XXX is the customer / program specific (-094, -192 etc.) and YYYY is the galley configuration (-1, -101, -1001 etc.). [12]

1.4.1 Characteristics of SA ACP project

All galleys and stowages are manufactured according to specific requirements that are specified by SA ACP project for A320 family aircraft. The SA ACP is a project of Airbus, during which the catalogue products were developed and designed including definition of the catalogue content itself. The reason, why Airbus has initiated this project is the aim to sell the aircraft including entire interior equipment – in so called SFE mode and therefore also the Galleys were needed to be delivered in SFE mode for majority of Airbus customers. Before the SA ACP, the majority of customers (airliners) were selecting their own supplier - galleys manufacturer to design, manufacture and deliver the Galleys as the Buyer Furnished Equipment (BFE). [6]

The dramatic increase of Galleys designed and delivered in SFE required also change of policy of product customization. Therefore, the SA ACP project moved Safran from position of Airbus partner and Airliners supplier into position of Airbus supplier – Key supplier for A320 Family aircrafts Galleys. [6]

Besides that, Safran has got a role of so called Integrator – supplying Galleys together with the Inserts (ovens, beverage makers, etc.) including their procurement. The above mentioned facts brought increase of demands on Safran design and production capacity and to its whole organization.

With the introduction of the SFE galley and stowage, Airbus is offering a large number of catalog stowage housings and options. The different possibilities to customize the stowage are allowing many different configurations to meet the airlines operational needs. From a simple coat stowage design up to a complex emergency equipment or trolley stowage the design will allow a high amount of flexibility. All options have been pre-studied by Airbus and a particular attention was given to allow a common design for replaceable items, like drawers, doors etc.

The stowage design is including a modular design concept for the industrialization process, but in difference to the galleys this modularity can't be retrofitted through individual modifications kits, due to the weight optimization and overall complexity in combining options.

The customization process of the stowage is starting with the selection of the installation location or area. In the second step the airline will have the choice between multiple base housings to serve different operational needs. Those base housings can be customized with optional arrangements, functions and features.

Galley consists of Green galley and Completion kit. Green Galley is basic structure and systems without equipment or completion kits (such as oven provision, various stowage, hot cup etc.). The Green galley is assembled from structure, water systems, air systems, electrical installation and galley installation kit. In principle, it is the part of the galley that is not changed due to configuration of the galley according to customer request. It contains provisions such as inserts and systems connections to install the completion kits for all of the available catalogue options for that galley. Green Galley CMM (Component Maintenance Manual) contains information relevant for Galley's family independent at configuration (such as diagrams, maintenance and servicing, etc.). [6]

Completion kit is equipment for each compartment (such as various stowage, container, preparation for oven, etc.) excluding inserts itself (such as oven, beverage maker, etc.) defined by customer based on required functionality of galley.

Galleys are installed in a transversal position in fuselage in full height. [13] Galley and its functional parts are shown in the *Fig. 1.7*.

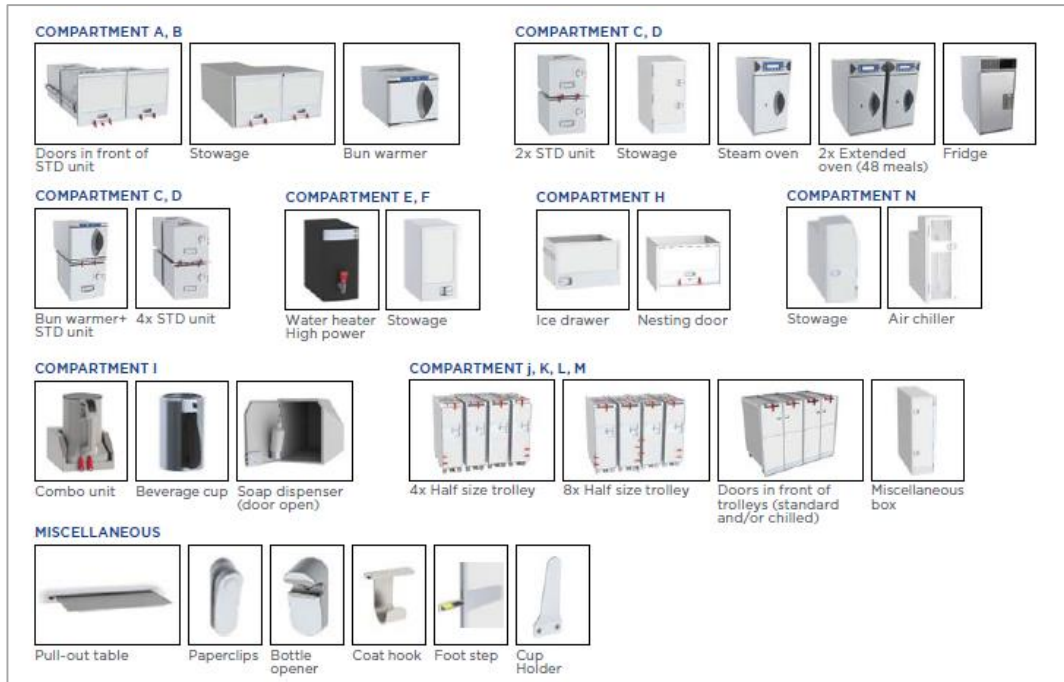


Fig. 1.7 Parts of a galley [10]

1.4.2 Types of aircraft within SA ACP. Galleys types and location in aircraft

The SA ACP project was dedicated to development of galleys and stowages for Airbus SA Aircraft namely A320 Family, which includes aircraft A318, A319, A320 and A321 shown in the Fig. 1.8. The main difference between these individual types is the length of the aircraft’s fuselage that determines number of seats and number of possible Galleys. [6]



Fig. 1.8 Family of aircraft A320 [6]

The galleys inner arrangements are only illustration of the possibilities offered to the airlines. All possible variation in accordance with Airbus catalogues will be enabled due to customers' requirements and catering equipment. Galleys and stowages can be differently assembled and placed in the fuselage. Each galley and stowage have weight, size, constraints and many other characteristics depending on the type. [6] Galley position is related mainly to the individual doors of aircraft and to the direction of the flight. The standard galley positions in fuselage of an aircraft are shown in the *Fig. 1.9*.



Fig. 1.9 The standard galley positions in fuselage [10]

2 Aviation certification, regulation authorities, documentation and fire properties qualification

Aircraft safety has always been a topic of high priority. Being the major responsibility agency for aviation safety FAA continuously makes an effort to maintain and intensify fire safety. It is performed by ensuring the safety of designs of new aircraft through the certification processes, inspection at different stages of manufacturing of new aircraft and of aircraft in use through strict maintenance. Beside specifications agreed between aviation manufacturers and purchasers, the materials used in aircraft constructions must comply with international

regulations. The Federal Aviation Regulations and a variety of documents, such as Aerospace Recommended Practices and technical reports involve enforcement of standing safety requirements. Plenty of special committees keep these requirements technologically current. Moreover, new standards for aviation fire safety and airworthiness are imposed in case of known or an immediate threat to safety, such as inappropriate features of specific aircraft models. [14]

2.1 Aviation regulation authorities

There are many different aviation regulation structures across the world such as ICAO, FAA, EASA, JAA and so on. Civil Aviation Authority (CAA) is a generic term used for a national regulatory body responsible for aviation. The Federal Aviation Administration (FAA) is the Civil Aviation Authority of the United States; European Union Aviation Safety Agency (EASA) is the main regulatory body in European Union (EU). The Joint Aviation Authorities (JAA) is a co-operation of most European (EU and non-EU) civil aviation regulatory authorities. Besides, the International Civil Aviation Organization (ICAO) safety standards and procedures cover worldwide civil aviation.

2.1.1 ICAO organization

ICAO is a specialized agency of the United Nations; the 193 Member States are within the organization and work together for developing international Standards and Recommended Practices (SARPs). SARPs are the reference for states that develop their national aviation regulation, which are legally enforceable. [15]

ICAO SARPs for each area of ICAO responsibility are contained in 19 Annexes. Each Annex describes a particular subject area. The constitution of the organization is the Convention on International Civil Aviation, which was written on a conference in Chicago in 1944. [16]

2.1.2 FAA authority

FAA is an operating mode of the United States Department of Transportation with powers to regulate all aspects of civil aviation with the usage of Federal Aviation Regulations (FARs). Safety is the core of the FAA's mission and its top priority.

FAA certifies the design of aircraft and components that are used in civil aviation operations. Aircraft certification has relied on the exchange of information and technical data,

which has helped to reduce risk of commercial aviation fatalities by 94 percent over the past 20 years. [17]

2.1.3 EASA organization

EASA was created in 2002 by the European Commission with responsibility for civil aviation safety. It is responsible for certification, regulation and standardization as well as performs investigation and monitoring. This agency analyses safety data and advises on safety legislation. EASA took over the functions of the Joint Aviation Authorities of the EU countries.

The responsibilities of EASA include drafting of aviation safety legislation and providing technical advice to the European Commission and to the EU Member States, airworthiness and type certification of aircraft and aircraft parts for aircraft operating in the EU, approval of aircraft design organizations worldwide and of the production and maintenance organizations inside and outside of the EU. Since the creation of organization, its competencies have gradually expanded. [18]

2.1.4 JAA authority

JAA was not a regulatory body itself and the member authorities were responsible for the regulation. JAA originally started as the Joint Airworthiness Authorities in 1970 and its objectives were to produce common certification standards for large aircraft and aircraft engines to facilitate a European aviation manufacturing industry, namely Airbus company. Over time, the scope was extended to included aircraft operations, licensing, maintenance, and certification/design standards for all aircraft classes.

With the creation of EASA in 2002, the EU members transferred the airworthiness regulations away from the JAA. Eventually, EASA became responsible for operations and licensing as well. In 2009 the JAA system was disbanded and only the training organization JAA-TO remains, which mainly provides courses for CAA staff of European countries. [19]

2.1.5 The Joint Aviation Requirements

The Joint Aviation Requirements (JAR) is a set of common comprehensive and detailed aviation requirements issued by the Joint Aviation Authorities. JARs intended to minimize Type Certification problems and to facilitate the export and import of aviation products. These

aviation requirements were recognized by the national aviation authorities as an acceptable basis to show compliance with their national airworthiness codes. [20]

2.2 Aircraft certification

Before a newly developed aircraft model may enter into operation, it should obtain a type certificate from the responsible aviation regulatory authority. Since 2003, EASA is responsible for the certification of aircraft in the EU and for some European non-EU Countries. This certificate proves that the type of aircraft meets the safety requirements set by the European Union. There are four steps of the type-certification process:

a) Technical Familiarization and Certification Basis

It defines that the aircraft manufacturer have to present the project to EASA when it is considered to have reached a sufficient degree of maturity. The EASA certification team and the set of rules that will apply for the certification of this specific aircraft type are being established.

b) Establishment of the Certification Program

It shows that EASA and the manufacturer need to define and agree on the means to demonstrate compliance of the aircraft type with each requirement of the Certification Basis. This goes hand in hand with the identification of EASA's "level of involvement" during the certification process.

c) Compliance demonstration

The aircraft manufacturer must demonstrate compliance of its product with regulatory requirements such as the structure, engines, control systems, electrical systems and flight performance are analyzed against the Certification Basis. This compliance demonstration is performed by analysis during ground testing (such as tests on the structure to withstand bird strikes, fatigue tests and tests in simulators) but also by means of tests during flight. EASA experts perform a detailed examination of this compliance demonstration, by means of document reviews in their offices in Cologne and by attending some of these compliance demonstrations (test witnessing). This is the longest phase of the type-certification process. In the case of large aircraft, the period to complete the compliance demonstration is set at five years and may be extended if needed.

d) Technical closure and issue of approval

EASA closes the investigation and issues the certificate, if technically satisfied with the compliance demonstration by the manufacturer. EASA delivers the primary certification for European aircraft models that are also being validated in parallel by foreign authorities for operation in their airspaces, for example, the FAA for the United States or TCCA for Canada. Contrariwise, EASA will validate the FAA certification of US aircraft models (or TCCA certification of Canadian models) according to applicable Bilateral Aviation Safety Agreements between the EU and the concerned Third Country. [21]

2.3 Fire properties qualification requirements

Aviation products demand extremely complex parts and large assemblies that should meet strict safety standards, satisfy customer requirements and also maximize performance. [22]

Usage of fire safe cabin materials for commercial aircraft is the objective to eliminate burning of cabin materials as a cause of death in aircraft accidents.

Inflight fires occur frequently in accessible areas such as the galleys and are usually detected and extinguished promptly. On rare occasions, inflight fires originating in inaccessible areas become uncontrollable leading to large loss of lives. Typically, inflight fire incidents were caused by electrical failures or overheated equipment. [23]

Fires on board an aircraft are the most severe from a fire safety perspective due to enclosed spaces hold heat and combustion products, which increase the fire hazard and its impact on passengers. Such fires become life-threatening when the fire propagates through the cabin generating heat, smoke, and toxic decomposition products. Hot combustion products rise from the fire entraining air and forming a hot and smoky layer below the ceiling, which deepens as the fire continues to burn. The availability of air influences the products of combustion as well as the intensity of a fire. As oxygen is used up during combustion, the portion of carbon monoxide in the smoke increases and becomes the primary toxicant in a fire.

FAA cabin measurements of fire hazards such as growth of temperature, release of smoke, carbon monoxide, oxygen deprivation and carbon dioxide show exceeding of individual and combined tolerance limits. [24] All these factors should be considered during the process of creating of aircraft interior design to be safe in fire. The ultimate evaluation of safety depends upon whether it is possible to ensure that the passengers can be expected to escape before they

are exposed to levels of heat and smoke that may endanger health and threaten life. In situations where the cabin or cockpit atmosphere becomes contaminated with smoke from small in-flight fires, it may be important to minimize the inhalation of irritant smoke. This might be done by increasing the rate of cabin air change to reduce smoke concentration, or in extreme cases by using oxygen masks. [14]

For fire properties, the most important factors are flammability, heat release, toxicity and smoke. Flammability is the ability of a chemical to burn or ignite, causing fire or combustion. The degree of difficulty required to cause the combustion of a chemical is quantified through fire testing. Usually materials are rated as highly flammable, flammable and non-flammable. It is important to know the flammability of materials for its safe storage and transport. That is why strict measures should be taken to prevent fire for flammable materials. [25]

Heat release is a measure of the amount of heat energy, which was evolved by a material during burning. It is expressed in terms of energy per unit area (kilowatt minutes per square meter - kW min/m²). Heat release rate is a measure of the rate of heat energy evolving by a material. The maximum heat release rate occurs when the material is burning most intensely. [26]

Toxicity is the degree to which a hazardous substance can harm passengers. [27] Regardless of its origin and exact composition, all smoke is toxic and poses a serious threat to the health of passengers. [28]

Smoke is a combination of the airborne solid and liquid particulates and also gases, which are generated while a material undergoes combustion and the air that they are mixed with. Particulate smoke is a product of incomplete combustion and is generated during both smoldering and flaming combustion. [29]

The key considerations with regard to in-flight fires must be prevention, limitation, detection and suppression. Aircraft materials, design, and construction are all planned with fire prevention in mind. Materials used in aircraft interiors are currently selected with a high fire performance specification in terms of ignitability. Flame spread, ignitability and heat release characteristics are all very important in terms of fire-initiation and growth. For fires in concealed spaces, early detection and the provision of suppression systems are very important as much as containment and fire stopping. As if the fire occurs in a sealed space, it will self-extinguish;

penetration of toxic smoke generated in the early stages of the fire into occupied areas is less likely to occur. [14]

Moreover, the increased use of flame-retardant materials for cabin furnishings has reduced smoke gas production during in-flight fires. [29]

2.4 Fire properties documentation

As aircraft and the materials used in their constructions must comply definite regulations, international standards are used at this moment all around the world. For writing this work I have investigated international documents such as JAR- 25 and PS-ANM-25.853-01-R2, which describe requirements for flammability testing of materials used in the interiors of transport category airplanes.

JAR -25 is based on Part 25 of Federal Aviation Regulations and is termed as Joint Aviation Requirements for Large Aeroplanes. JAR -25 describes airworthiness standards for large planes including A320 aircraft family. JAR -25 the European equivalent of the FAR part 25, especially the appendix F describes all the test methods for materials and components of the pressurised section of fuselage. [30] This Code prescribes airworthiness JAR-25 standards for the issue of type certificates, and changes to those certificates, for Large Turbine-powered Aeroplanes, which means aircraft with a maximum takeoff weight exceeding 5,700 kg.[31]

Since electrical wires are one of the subjects of this work, the part of JAR about wire testing is mentioned. JAR 25.869 Fire protection: systems states that insulation on electrical wire and electrical cable installed in any area of the fuselage must be self-extinguishing when tested in accordance with the applicable portions of Part I of Appendix F. [32]

FAA PS-ANM-25.853-01-R2 is the Federal Aviation Administration Policy Statement No PS-ANM-25.853-01, which subject is the flammability tests of aircraft interior materials. It is titled as Flammability Testing of Interior Materials Policy Statement released on July 3, 2013. This policy statement provides guidance on acceptable methods of compliance with the flammability requirements of Title 14, Code of Federal Regulations (14 CFR) part 25 for commonly constructed parts, construction details, and materials. The information in this Policy Statement is only a summary of the extensive substantiating data gathered regarding flammability testing of interior materials. [33]

2.5 Fire properties evaluation and flammability tests

In aviation industry, flammability tests are performed with the usage of different types of Flammability Test equipment such as Horizontal Flammability Chambers, Vertical Flammability Chambers, 45-degrees Test Chambers, 60-degree Test Chambers and so on. These chambers are used in various areas of fire testing of materials and are specified in Appendix F of Part 25 in the Federal Aviation Regulations. Different specimens of aviation materials are inserted to Flammability Test Chamber where flame impact is terminated at the desired time; it is used to determine the flame propagation and after flame time of materials. [34] After that, the assessment of the burning behavior of internal materials used in aircraft can be made.

The Test Chambers are simple to use, the cabinet is made of high quality stainless steel. It also offers automatic start test and a digital timer, which automatically controls gas flow. It has ergonomic design and is ideal for use in quality control applications. A wall mounted variable speed extraction hood assists to remove the contents of the chamber during and after testing. Approximate weight of a chamber is 60 kilograms. Its length is 330 millimeters (mm), width is 752 mm and height is 832 mm. It is designed for 230V AC supply at 50Hz frequency. It operates at ambient temperature from 10°C to 35°C. For burner gas supplying, the preferred fuel gas is methane with a minimum purity of 99% used in the test. The pressure required to obtain flame stability is approximately 17200 Pa. For effluent removal, an extraction hood is recommended to be situated above the chamber to take away produced smoke effluent. [34]

These types of aviation test equipment fully complies with FAA, Airbus and Boeing specifications and reflects the recent changes to the FAA handbook test specifications. [34]

There is the table of fire and flammability tests that are made for EASA, AIRBUS, BOEING and Dassault Aviation companies and documents where the tests are specified shown in the *Fig. 2.1*. [35]







RESCOLL 8, allée Geoffroy Saint Hilaire F-33615 Pessac Cedex Tél : + 33 547 74 69 00 www.rescoll.fr		Fire & Flammability Test			
TOPIC	CS 25, Appendix F FAR 25, Appendix F  	AITM (ABD0031) 	BSS (D6-51377) 	CS 25, Appendix F 	
Flammability & Flame Propagation					
Vertical Bunsen burner, 60s	Part. I, §(a)(1)(i)	AITM 2-0002 A	BSS 7230 F1	Part. I, §(a)(1)(i)	
Vertical Bunsen burner, 12s	Part. I, §(a)(1)(ii) & (iii)	AITM 2-0002 B	BSS 7230 F2	Part. I, §(a)(1)(ii) & (iii)	
Horizontal Bunsen burner, 15s	Part. I, §(a)(1)(iv)	AITM 2-0003 A	BSS 7230 F3	Part. I, §(a)(1)(iv)	
Horizontal Bunsen burner, 15s	Part. I, §(a)(1)(v)	AITM 2-0003 B	BSS 7230 F4	Part. I, §(a)(1)(v)	
60° Bunsen Burner, 30s (Cable/Wire)	Part. I, §(a)(3)	AITM 2-0005	BSS 7230 F5	Part. I, §(a)(3)	
60° Bunsen Burner, 30s (Heat Shrinkable Tubing)	Part. I, §(a)(3)	AITM 2-0038	BSS 7230 F6	Part. I, §(a)(3)	
Flammability of Seat Cushions	Part II	N/A	BSS 7303	N/A	
Heat release					
Heat release	Part. IV	AITM 2-0006	BSS 7322	N/A	
Smoke density					
Smoke density Flaming Mode Only	Part. V	AITM 2-0007 A	BSS 7238	N/A	
Smoke density Flaming and Non-Flaming Mode	N/A	AITM 2-0007 B	N/A	N/A	
Smoke density Electrical Wire/Cable for Power Supply	N/A	AITM 2-0008 A	BSS 7238	N/A	
Smoke density Electrical and Non-Electrical Cable for Signal/Data Transmission	N/A	AITM 2-0008 A/B	BSS 7238	N/A	
Smoke toxicity					
Smoke toxicity	N/A	AITM 3-0005	BSS 7239	N/A	
Flame Penetration					
45° Bunsen Burner Test, 30s	Part I, §(a)(2)(ii) & (iii)	AITM 2-0004	N/A	Part I, §(a)(2)(ii) & (iii)	
Flame Penetration Resistance of Cargo Compartment Liners	Part III	N/A	N/A	N/A	
Flame Penetration of Thermal/Acoustic Insulation	Part VII	N/A	N/A	N/A	

Fig. 2.1 The table of flammability tests [35]

2.5.1 Flammable properties of electric wires and wire insulation

There is a huge probability of fire within not accessible for extinguishment areas of aircraft. Wire and cable fire became the common reason of fire disasters. Moreover, fires involving electric wires can present a problem even in small flaming fires due to the organic irritants and acid gases that evolve. [14] That is why there is additional investigation of flammability of materials contained within hidden areas of aircraft. Moreover, stricter requirements for hidden area materials were introduced with the aim to limit the propensity of materials within these areas to spread a flame to other areas of the aircraft. [36]

The main purpose of wire insulation is to prevent contact of live electric conductors. It is usually made of non-conductive materials with excellent dielectric properties such as plastics, glass, oil or rubber. It is needed for insulation to be flexible and resistant to fracture caused by mechanical stresses. [36] JAR-25 also states that wires in designated fire zones must be fire resistant and meet the applicable fire requirements. [32]

Wires insulated with polymeric materials and PVC (polyvinyl chloride) blends being the most common application for low voltage systems. Aircraft wiring is typically more fire resistant, as PVC/Nylon wiring was found to be very flammable. [36] Typical aircraft wiring and its materials are shown in the *Tab. 2.1*.

Tab. 2.1 Typical aircraft wiring [36]

DESIGNATION	COMPOSITION
M5086/1,2	PVC/Nylon
M81381	Aromatic Polyimide (KAPTON)
M22759/34	Cross-Linked ETFE
M22759/80-92	PTFE/Polyimide composite (TKT)
M22759/11	TEFLON (PTFE)
M22759/18	TEFZEL (ETFE)

Effective analysis of wire insulation flammability is critical for testing wires that are used in the aviation market. FAA obligates that electrical wire insulation installed in any area of the fuselage must be self-extinguishing and tested in accordance with the sixty-degree flammability test specified in Appendix F of JAR-25. [32] The 60-degree Bunsen Burner test is used to determine the resistance of cable and electric wire insulation to a flame applied for 30 seconds.

[38] Sixty-Degree Bunsen Burner Test method states that a minimum of three specimens of each wire specification must be tested. The specimen must be placed at an angle of 60-degrees with the horizontal. It is exposed to a Bunsen burner flame and in 30 seconds pulled away from the sample. There are requirements in conformity with this test, which states that the average burn length may not exceed 3 inches; the average flame time after removal of the flame source may not exceed 30 seconds. Drippings from the test specimen may not continue to flame for more than 3 seconds. JAR-25 states, that the burner must be positioned so that the hottest portion of the flame is applied to the test mark on the wire. Flame time and flaming time of drippings, if any, must be recorded. [32] 60 degree Bunsen burner test set up is shown in the *Fig. 2.2*.

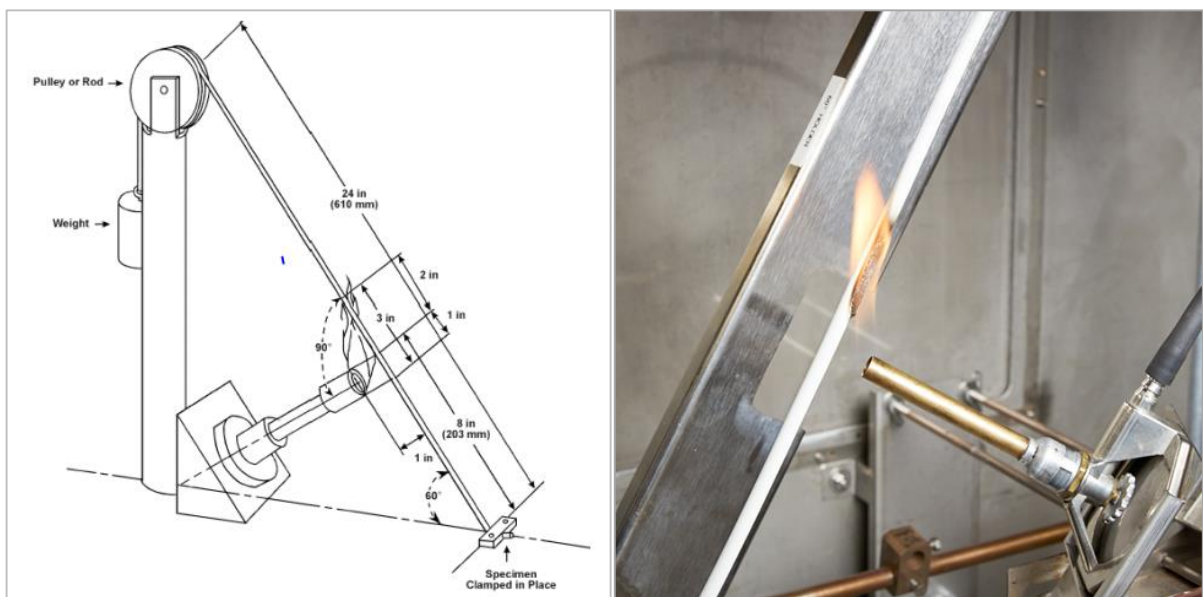


Fig. 2.2 60 degree Bunsen burner test setup [37] [38]

In the certification department analysis of materials used in manufacturing, small parts are not subjects to tests for flammability. Electrical cables and wires can never be considered as small parts and must always be tested. Information about wire testing is specified in JAR 25.869 Fire protection: systems and in Appendix F of JAR25. The F06 flammability test used for testing of cables and wires in Safran Cabin s.r.o. Certification department is shown in the *Fig. 2.3*.

F06 (60°)	Nomenclature:	Flammability – 60°
Requirement:	JAR 25.869 (a)(4) and Appendix F, Part I, (a)(3) (ref. AITM 2.0005)	
Test Specimen:	30" (762.0 mm)	
Acceptance Criteria:		<ul style="list-style-type: none"> - Average burn length must not exceed 3 inch. - Average after flame time must not exceed 30 seconds. - Drippings may not continue to flame for more than 3 seconds (average) after falling.

Fig. 2.3 The F06 flammability test

The F07 flammability test is used for testing of the shrinkable sleeve on wires. It is not the FAR /JAR test and is tested only for Airbus. The F07 test is shown in the Fig. 2.4.

F07 (HST)	Nomenclature:	Flammability – Heat Shrinkable Tubing
Requirement:	Airbus ABD0031 rev. G, section 2.3.1, AITM 2.0038	
Test Specimen:	Length of at least 610.0 mm (24")	
Acceptance Criteria:		<ul style="list-style-type: none"> - Average burn length must not exceed 3 inch. - Average after flame time must not exceed 30 seconds. - Average after flame time of drips must not exceed 3 sec..

Fig. 2.4 The F07 flammability test

3 Fire properties report description. The current state of the 3D system, the approach to creating a Fire properties report. Determination of key changes needed to be implemented to 3D system to enable automatic creation of Fire properties report

3.1 Fire properties report description

Report is a document, which contains information organized in a narrative, tabular or in graphical form that is written for a particular purpose, periodically, regularly, or as required basis. Reports may refer to specific subjects, periods or events. [39]

Fire properties (FP) report is a written document made on the basis of special template in Microsoft Word, formatted with a specific structure and layout. FP report is a document that compares the non-metallic materials of galleys and stowages to the official catalogs and is created by fire properties department. FP report includes a large number of data, such as references to regulatory documentation, description of size of materials, its properties and

combinations, used glue and other components used in the manufacturing of the products as required by regulatory certification. [40]

For every type of galley and for stowage there is a catalogue report. This enables the preparer of FP report to show compliance only for materials not listed in the catalogue report.

The main objective of FP report is to determine whether customer specific non-metallic materials used in galley or stowage manufacturing meet the relevant fire performance requirements. Flammability is the most important factor in choosing the type of material that should have a high fire resistance, which is determined during fire tests. In addition, in order to add a single material to the production, the certification department engineers have to consider various factors such as heat release, smoke and toxicity of the materials.

For every project there must be a fire properties report must made. The purpose of this report is to show compliance with FAA / JAR requirements for fire containment and fire properties of all non-metallic materials used in every galley or stowage in a project. If the requirements are not met, the galley or stowage cannot be mounted on to the aircraft. [40]

3.1.1 Structure of Fire Properties report

Fire properties report consists of:

1) Title page

The header on the title page should be in line with the latest certification information bulletin (CIB) document. Heading should be done according to the special CIB-17-002 bulletin heading template. Name of the airlines should be according to the special CTS document. FP report is always named after the name of the first assembly in the project. The code is created by changing the first three numbers of the final assembly name from 601 (FA – final assembly) to 460 (FP - Fire Properties). After the document number, the revision must be written, where NC is initial release and A, B, C and so on are subsequent revisions. After that, all galleys and stowages that are contained in the report are listed.

Three people must sign the report: the person, who prepared the report, the person with checker status, which is responsible for the report correctness and the person, who approves the report. The footer is standard in every report and should be written according to the template. [40]

2) *Revisions*

Every revision of the report must be written to the revision list. If the report is initially released, there should be NC in the first column and Initial release in the description. The date and the approval are filled manually according to the date when the report is finished by the preparer.

If the new revision of the report is released, then there must be all changes described and the previous state of items stated. It was mutually agreed that the revision log would be standardized according to the revision log.

3) *Table of Contents*

Table of Contents is generated automatically and must be updated before the report is finished.

4) *Introduction*

This chapter contains the subject of the report, its purpose and also references to the necessary documents.

5) *Requirements*

The requirements are the same in every report and should never be changed.

6) *Fire containment substantiation*

This section is used to show the fire containment compliance. Fire containment substantiation table is shown in the figure 16.

7) *Fire properties substantiation / comparison*

This section is intended to show compliance with FP requirements that are defined in the section Fire Properties. This section is used for galleys only. Compliance for stowages is shown in separate section, which has identical structure as galley section. The text in the first section is standard and should be the same for every report.

8) *Conclusion*

This chapter concludes that non-metallic materials used in galleys and stowages construction meet the applicable fire performance requirements.

9) ANNEX

Annexes are used for the test results of the flammability tests of non-catalog specimens. The test results always start with SCS (specimen configuration sheet) where the whole buildup, material and tests are described. After that the test results follows. Every annex is named after its SCS. [40]

3.2 The current state of the 3D system

Product Data Management (PDM) Smartteam is the name of an entire system that serves as a document management system and a database of technical drawings and 3D models that are used in the design of galleys and stowages. It also places datasheets, various excel configuration documents as well as General Arrangements. General Arrangement is a document, which presents the overall composition of an assembly.

Document management system (DMS) is a system designed to manage electronic documents or digitized paper documents. DMS has the task to provide any user with instant and secure access to business documents. In practice, when using the DMS system, electronic documents are stored using a form that contains all the necessary information used to control user access to the file and keeps track of all activities that happen with the document. [41]

PDM Smartteam gives the engineers the opportunity to import required data, store it securely, and maintain its accessibility.

Designers and engineers must constantly innovate large assemblies by changing modifications of existing parts according to the new orders. These processes require special software and effective technologies such as CAD software. A computer-aided design (CAD) is a design technology that allows drawing of extensive technical 2D and advanced 3D models. [42]

SOLIDWORKS is one of the most popular computer-aided design software tools available. It has been implemented by a wide range of industries such as aviation engineering, mechanical engineering, product design, 3D animation and others, who benefit from the advanced capabilities of this software. [43] SOLIDWORKS product development solutions simplify all design process and accurately evaluate product performance and safety. It also helps to achieve efficient and cost-effective movement from design to manufacturing. [44]

3.3 Approach to creating Fire properties report

BOM (bill of materials) is a document created in Microsoft Office Excel that describes the materials used for every part of a particular assembly of galley or stowage. In BOM, each assembly is completely divided into each small level. It is an essential tool for the fire properties department, because the compliance for each material or part of the galley should be shown. BOM is downloaded from the Infor ERP LN System database. [40] Infor LN is enterprise resource planning (ERP) software that offers fast and cost-effective deployment with integration on the shop floor and across the supply chain with financials, quality management, service management and order management. [45] In Safran Cabin CZ certification department, Infor ERP LN system is used for storage of different documents and BOMs as well.

To facilitate the work for certification department engineers, the macro has been created. Macro is a piece of programming code that runs in an Excel environment, which solves problems by automating routine tasks. It is very convenient to use macro. [46] Certification macro is the specific function in Excel, helping to evaluate and characterize materials automatically according to their properties such as dimensions, used adhesives, whether it is a metallic part or not. Due to macro created by certification engineers, BOM can be automatically converted and pre-filled by macro, which contains instructions for automatically creation of the data table. Depending on whether the part of the assembly is metallic, partially metallic, or manufactured from other materials such as plastics, the rows of the table are automatically colored with certain colors. [40]

3.3.1 Inputs required for Fire Properties report

The Fire Properties report is generated automatically by a macro in Excel and it is based on the data that has already been automatically processed in BOM. First, it is needed to name the report, which will always have the same name as the first project report.

Furthermore, the report must include all component and assembly notes as shown in the 3D system drawings. It is important to know which materials are used to make the individual parts and also which adhesives are used in the design of the assembly. Main steps that should be performed for creating a Fire Properties report are shown in the *Fig. 3.1*.

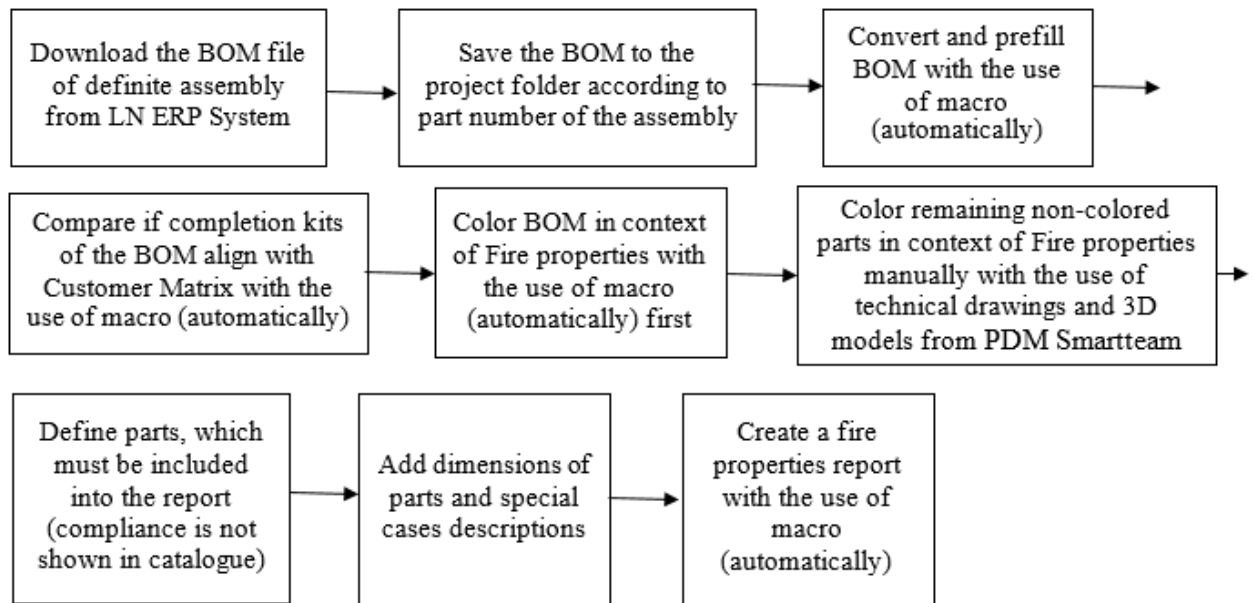


Fig. 3.1 Steps for Fire Properties report creation

3.4 Detected disadvantages of the current 3D system

While working in the certification department, I was looking for the disadvantages of the current 3D system and I also consulted with the supervisor of the diploma thesis and colleagues. I was involved in creating Fire Properties reports, for which I used 2D drawings and 3D models and other information that I found in the PDM Smartteam system. In addition, I used an automatic macros in Microsoft Excel for automatic filling of information about the materials used in manufacturing of galleys and stowages. I have identified a number of gaps in these processes and described it.

- ***Lack of standard types of materials in SOLIDWORKS***

The first disadvantage of the current system is that there are not enough standard types of materials in SOLIDWORKS application to identify materials of specific parts and assemblies. Special types of materials should be newly created or outdated one should be updated in SOLIDWORKS. Therefore, the right materials are not correctly defined.

- ***Slow opening of 3D drawings in SOLIDWORKS***

The second disadvantage is the slower opening of the model draft in 3D compared to the opening of the 2D drawings. In addition, the 2D drawing includes more information about the part or assembly than the 3D model, where no data is listed except the dimensions of the part.

- ***Difficulties of creating 3D drawings description in SOLIDWORKS***

Another disadvantage is that it is difficult to enter all notes on 3D drawings, such as adhesives, double-sided tapes, etc.

- ***Possible mistakes of automatic macro***

The last drawback of the current system is that the description of the materials used in BOM is performed by an automatic macro, which sometimes may not work correctly.

To eliminate these disadvantages, it is necessary to make technical changes in the 3D system to optimize and accelerate work with the database.

3.5 Technical changes in the system for creating of Fire properties report using 3D data

As it was already mentioned, in the Safran Cabin CZ s.r.o. certification department all data analysis is performed manually or by using macros in Microsoft Word and Microsoft Excel software. All reports are saved in Word format; all supporting documents as BOM tables are saved in Excel format. The most important information for Fire Properties report is dimensions and materials of parts in assemblies of galleys and stowages. All necessary information about assemblies can be found in 3D system in the form of 2D technical drawings with descriptions, such as dimensions, materials and glues used or massive 3D models, where only dimensions of parts are described.

First of all, it is necessary to make changes to the 3D system so that all components and assembly notes such as dimensions and materials of assemblies are listed on the 3D model. This can be accomplished by adding notes to the design table in SOLIDWORKS.

A design table is a configuration table that allows creating multiple part or assembly configurations by specifying parameters in a Microsoft Excel embedded worksheet. [47] The design table can be saved in the model file and initially was not linked to the original Excel file. Therefore, it is needed to link the model file to the Excel file for showing data with characteristics of the part materials on the 3D drawing. When using design tables, it is necessary to format these tables properly.

As a result, when searching for a particular 3D model of assembly in the 3D system, it will be possible to see not only a 3D drawing, but also a table with data about every part of assembly near a model. In this case, during preparation of Fire properties report it is possible to use directly the 3D model database as a data source. By connecting the report with the design table, we ensure easy access to data for both FP reports preparation and for preparation of the rest of the documentation.

It would be very within engineering works to use a single BOM for every huge assembly from a CAD model. It will be possible to define, collaborate, and predict how designs will perform so they can be optimized before they are built.

4 Practical part performed in SOLIDWORKS software and SOLIWORKS description

4.1 Description of CAD application SOLIDWORKS

Computer-aided design (CAD) is a computer technology, which helps to design a product and documents the process of designing. It facilitates the manufacturing process by transferring detailed diagrams of a product materials, processes, tolerances and dimensions with specific conventions for the product in question. CAD can be used to produce two-dimensional (2D) and three-dimensional (3D) graphs, which can be viewed from any angle with the help of rotation, even from the inside looking out. [48]

CAD technologies can be used with such aims:

- To create conceptual design, product layout, strength and dynamic analysis of assemblies and different manufacturing processes.
- To produce detailed engineering designs, 2D and 3D drawings of the different components of manufactured products.
- To prepare environmental impact reports, where these designs can be used in photographs to produce a rendering of the appearance when the new structures are built. [48]

SOLIDWORKS is a professional 3D CAD modeling software for automation of technical design using the Microsoft Windows graphical user interface. Using this software, it is very easy

to create technical drawings of individual models and complete assemblies. SOLIDWORKS offers a complete solution for any design and also has a simple intuitive environment. In addition, SOLIDWORKS allows to work with large assemblies and create large drawings. [49]

With this software, designers and engineers can make changes to designs quickly, solve design problems, and economically construct products, when the program automatically detects errors early. The main SOLIDWORKS window is shown in the Fig. 4.1.

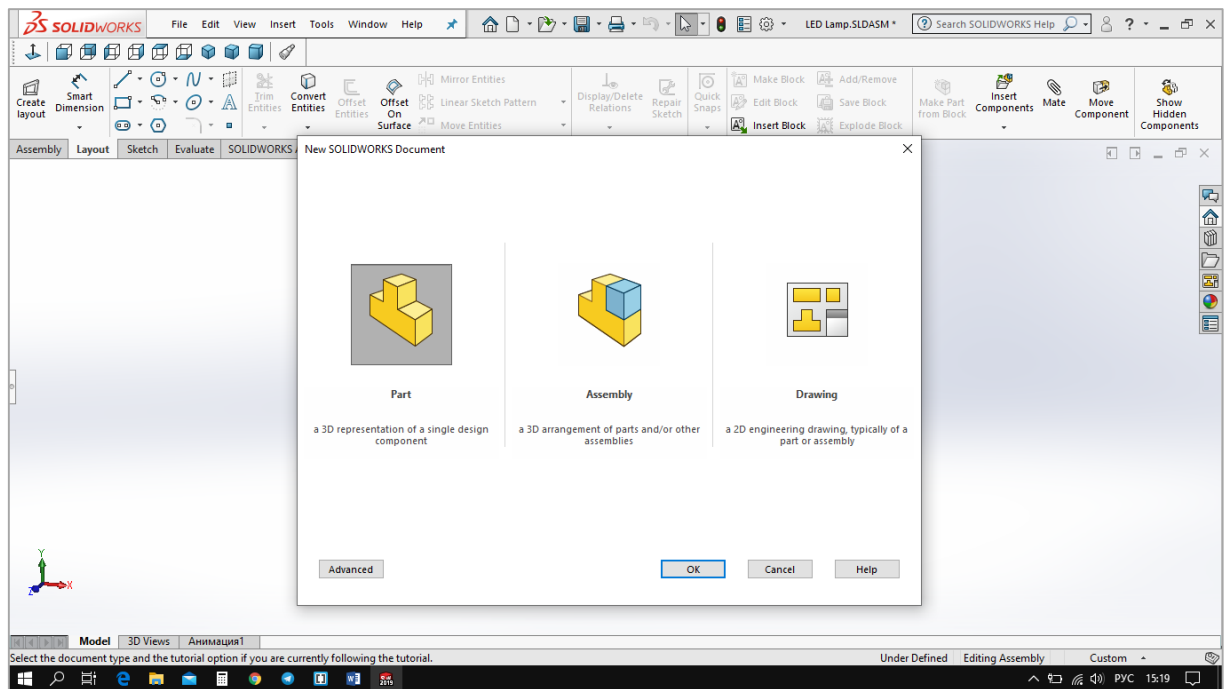


Fig. 4.1 The main SOLIDWORKS window

4.2 Brief description of the technologies used

The realization of the assigned task is performed with definite steps. First, it is needed to create a small assembly model in CAD software. As all galleys and stowages are huge assemblies, the most convenient way to show how the approach for Fire Properties report creation will work after implemented changes, is to create a Fire Properties report for a small assembly.

I was proposed to create a 3D model of small aircraft cabin LED light, which is a part of galley assembly. After that, the description table should be made in CAD software to define all parts and materials that are used in construction of this light. Then, completed table can be

imported to Excel document and be analyzed manually or by usage of macros. After that, FP report for LED light will be created.

After completion of the task, the resulted approach can be implemented for all assemblies and parts of different dimensions that are present in the 3D system in the Certification department.

4.3 Description of creation of 3D model of LED light in CAD program SOLIDWORKS

4.3.1 Description of LED light

LED low profile light PMA model with 0204197 part number is manufactured by Luminator Technology Group in the United States. It is 191 mm long and 64 mm high. LED light is applied for aircraft cabin and fits into .50-inch panel for space limited galley, closet or other task lighting installations. Voltage options are available in alternative and direct current. No external transformer required for 115 Volt alternating current applications. [50]

To create the 3D model of the LED low profile light, which is used in aircraft interior design I had to disassemble into small parts. The construction of the lamp consists of 4 main big parts and small parts such as bolts, latch parts, wire clip, diodes, capacitors and switch. The photos of LED light back and front sides are shown in the *Fig. 4.2* and *Fig.4.3*.

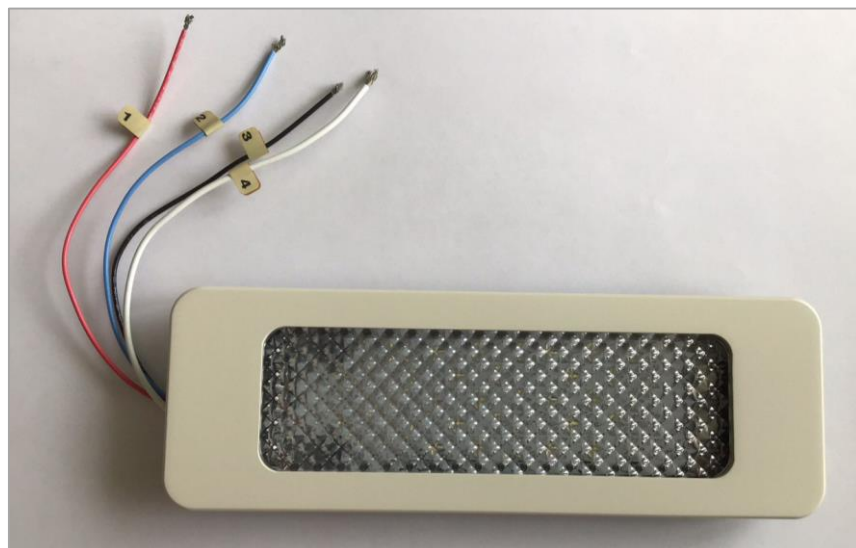


Fig. 4.2 LED lamp front side

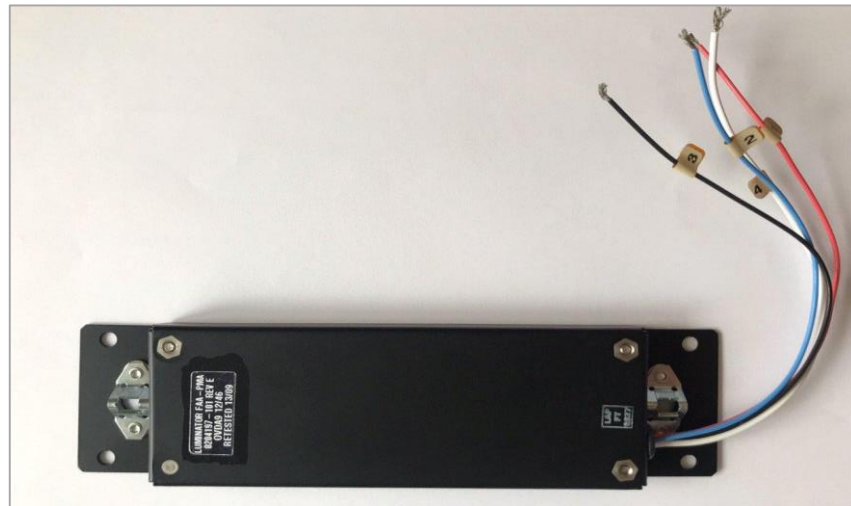


Fig. 4.3 LED lamp back side

The white front part and black back parts are made of stainless steel shown in the *Fig. 4.4* below. The front opaque white part, which covers diodes, is made of plastic shown in the *Fig. 4.4* above. Printed circuit board with diodes, 4 capacitors and one switch is made of fiberglass. Each of two latches consist of three small metallic parts, which keep all parts together.



Fig. 4.4 Metallic front and plastic middle construction parts of LED light

Metallic back part is connected to the printed circuit board with the help of 4 bolts. White, black, red and blue wires are attached to the circuit board and are hold together with the usage of cable clip made of rubber. Circuit board of the LED light is shown in the *Fig. 4.5*.

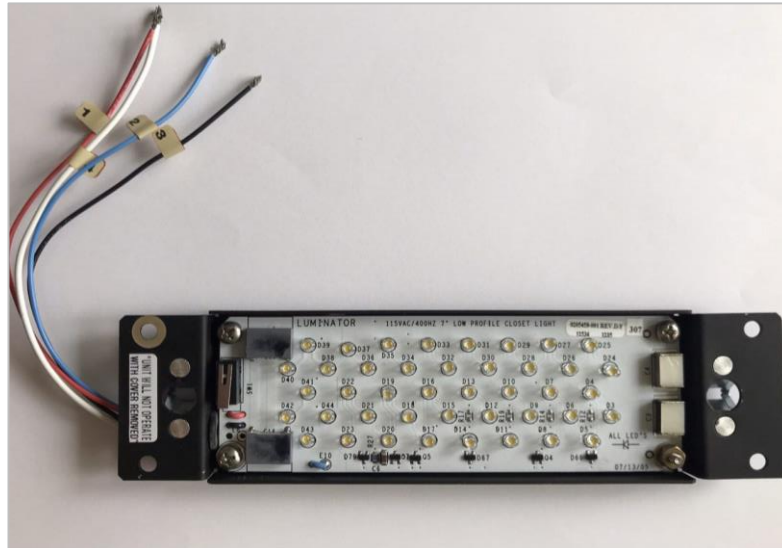


Fig. 4.5 Metallic back part connected to the printed circuit board

4.3.2 Procedure of 3D model creation

With the help of CAD application SOLIDWORKS I have created the 3D model of the LED low profile light. To begin new SOLIDWORKS project I have chosen PART in the New SOLIDWORKS Document window. To create the model of front white metallic part of LED light I had to create a 2D sketch of the model. First, I have created a rectangle with the help of the option Corner Rectangle. I have rounded the corners with the help of Sketch Fillet icon. To add a volume to object I have used the feature Extruded Boss/Base. I have added rounded external face along edges with the help of Fillet feature. To create a thin-wall feature I have used Shell icon. After that I have created a sketch of rectangular with rounded corners and cut through it in the middle of the body with the help of Extruded Cut. Two rectangular notches were cut with usage of the same feature. After that, I have created a sketch of rounded fastening part, extruded it with the feature Extruded Boss/Base and mirrored it for the different side with Mirror icon. Created front part of LED light in SOLIDWORKS is shown in the Fig. 4.6.

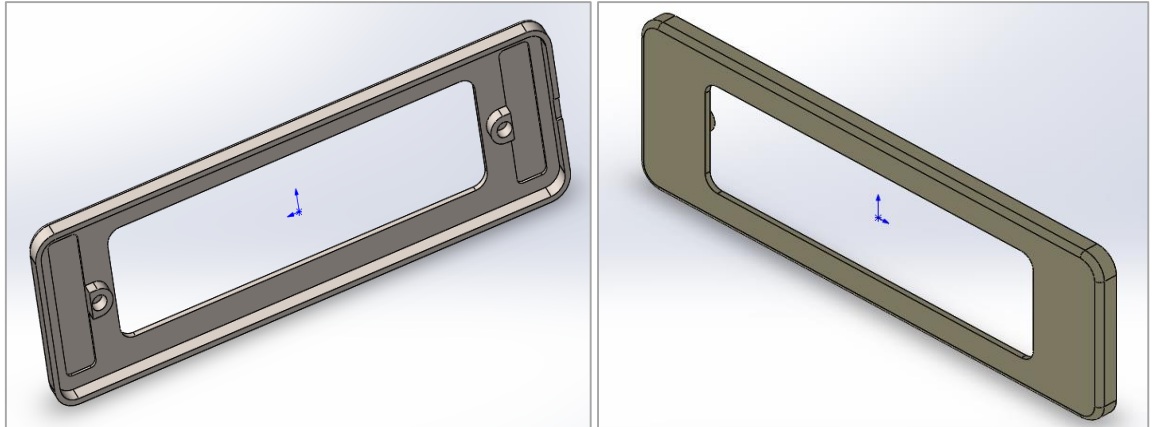


Fig. 4.6 Front and back view of metallic front part

To create the model of back metallic part I have created a new part, made a rectangular sketch and used a feature Sheet Metal with 1 mm thickness. I added two curved parts from right and left sides of the model with the help of Base Flange/Tab icon. After that, I added two walls with the help of Edge Flange feature. Then, I have created sketches of five circles from two sides and cut it by clicking on Extruded Cut icon. Created back part of LED light in SOLIDWORKS is shown in the Fig. 4.7.

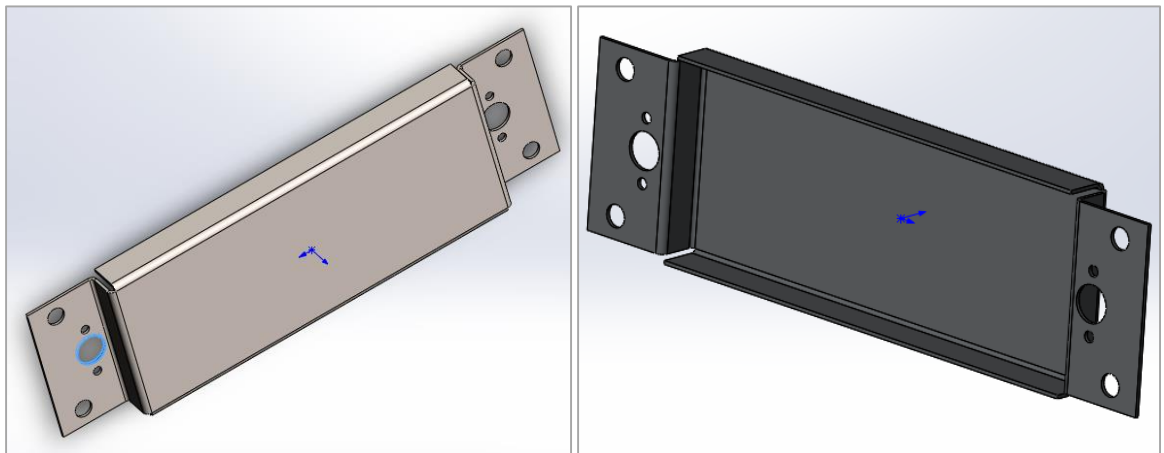


Fig. 4.7 Front and back view of metallic back part

The latch is made of three small metallic parts, which keep the lamp parts together by connecting the front and the back metallic parts of the LED light. To create models of the latch parts I have created three sketches.

The first latch part I have created with Line and Circle features, rotated sketch with the help of the option Revolved Boss/Base, made the hexagon on the underside with the Polygon feature and cut ribs with Extruded Cut and by clicking on Flip Side to Cut.

The second latch part I have created with the Sheet Metal feature. I have made a sketch, rounded edges by Sketch Chamfer feature, added two round and one rectangular sketches and cut it with Extruded Cut feature. I have stretched out the edges with the help of Edge Flange feature.

For creation of the third latch part I have made a sketch and turned it on 360 degree with Revolved Boss/Base feature. Models of three parts are shown in the *Fig. 4.8*.

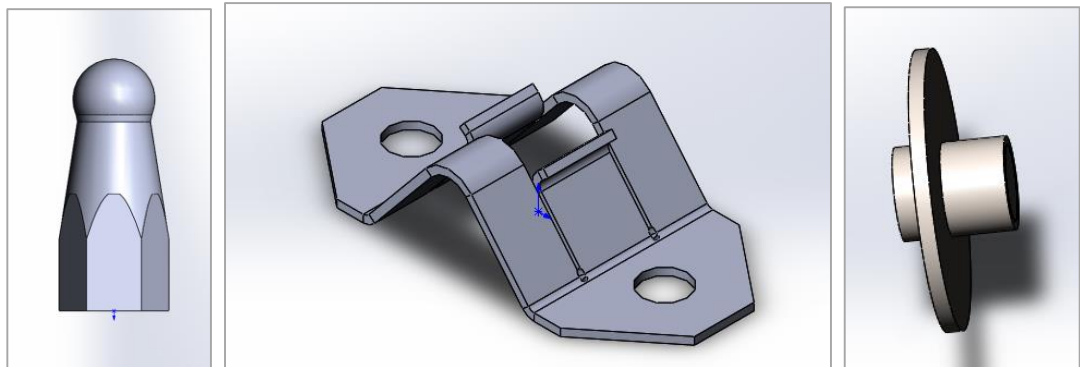


Fig. 4.8 Latch parts

For creation of the middle plastic part, I have started with adding a new part, made a rectangular sketch by clicking Corner Rectangle icon, cut away the corners by clicking Sketch Chamfer icon and added thickness to object by usage of the feature Extruded Boss/Base. After that, I have created a rectangular sketch with rounded corners and extruded it with Extruded Boss/Base icon. I have and drawn an oval on one side of the model, cut it with Extruded Cut feature and made it on the other side with the help of Mirror feature. Created middle part of LED light in SOLIDWORKS is shown in the *Fig. 4.9*.

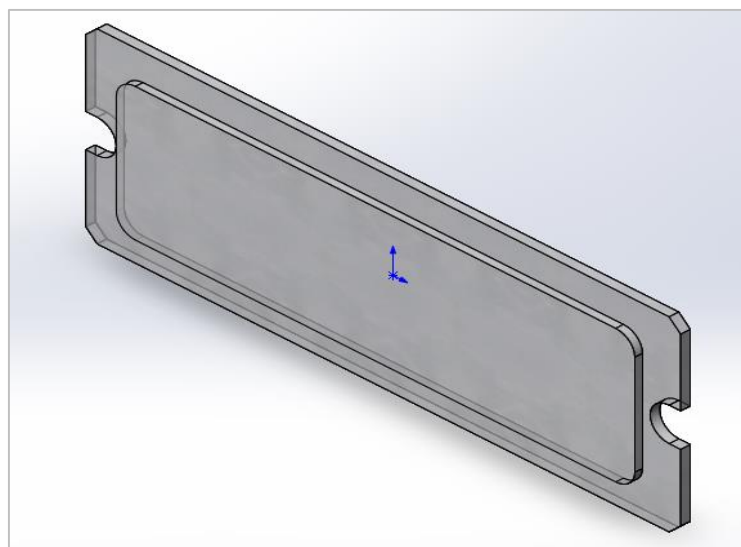


Fig. 4.9 Middle plastic part

I have created an assembly of the circuit board, 42 diodes on it, four capacitors and one switch. The circuit board is connected to back metallic part with the use of four bolts, which I have downloaded from Design Library Toolbox as Oval Head B18.6.7M M3 x 0.5 x 8 Type. The bolt is shown in the *Fig. 4.10*.

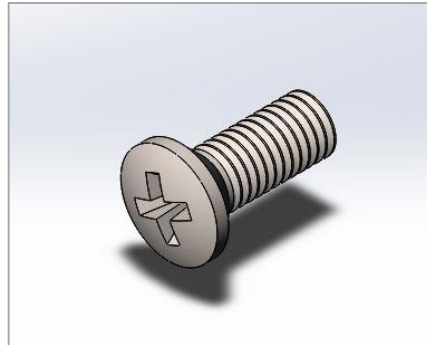


Fig. 4.10 Bolt for connection of back metallic part and circuit board

To create a circuit board I used the same features as for the middle plastic part creation. Then, I made sketch of diode, added sketch of 41 points in 5 rows on the front plane of the circuit board and connected diodes with points by using Linear Pattern feature and Sketch Driven Pattern icon. After that, I have created five rectangular boxes of different sizes with the Corner Rectangular icon and the feature Extruded Boss/Base. I have connected all the parts with the Mate feature. Finished model of circuit board with capacitors, switch, diodes and bolts is shown in the *Fig. 4.11*.

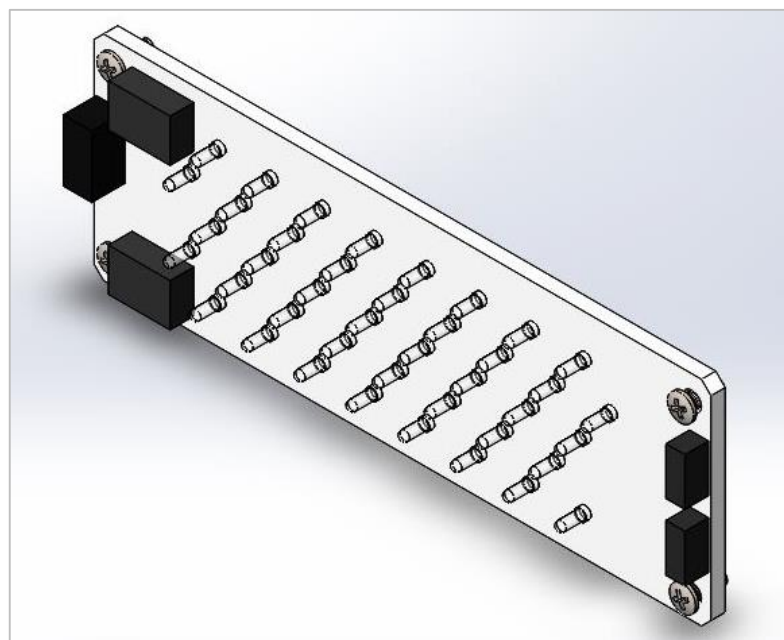


Fig. 4.11 Circuit board of LED lamp with bolts

For creation of the cable clip I have made a sketch with Lines feature, rotated sketch with the help of the option Revolved Boss/Base and rounded edges by clicking Fillet icon. Created model of cable clip is shown in the *Fig. 4.12*.



Fig.4.12 Cable clip model

To create the model of wires with insulation I have made four lines with Line feature, tied them together using the Mate feature and stretched it out with Swept Boss/Base feature. Created wires with insulation are shown in the *Fig. 4.13*.

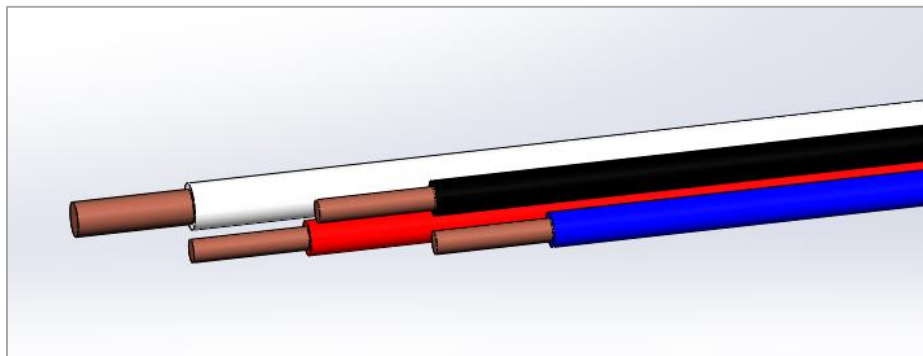


Fig. 4.13 Wires model

For all models, I added color using the function Appearances by clicking Color icon and added the materials from SOLIDWORKS Materials standard library.

After creation of all parts models, I have connected it in assembly by clicking Mate in Assembly toolbar. I edited mates between parts by expanding the Mates folder in the Feature Manager design tree and selected Edit Feature.

Finished model of the LED low profile light is shown in *Fig. 4.14*.

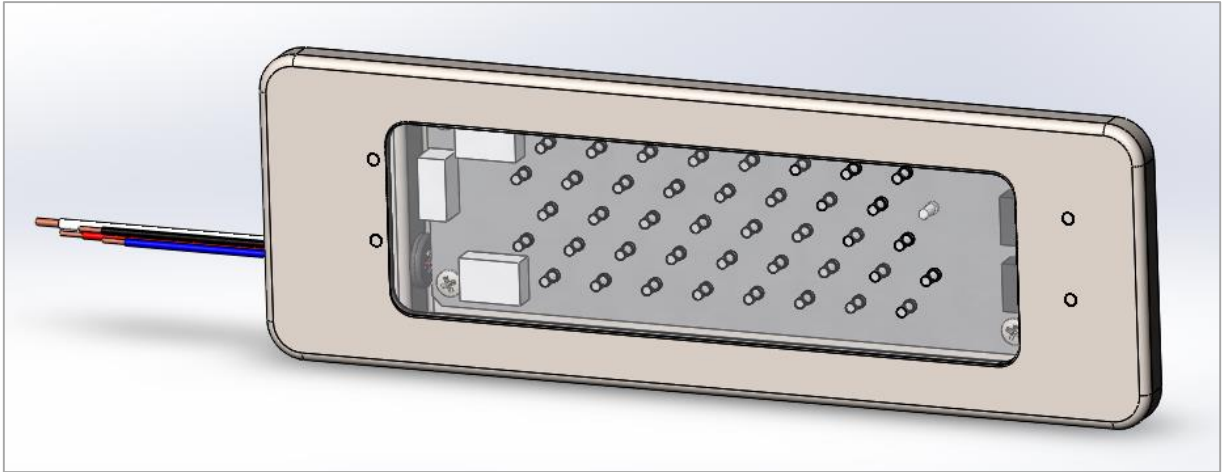


Fig. 4.14 Completed LED lamp model

4.4 Connection of a 3D model and the database of materials in SOLIDWORKS using the Design table

To connect created model and data of its characteristics I used the standard function Design Table in SOLIDWORKS. First, I added numbers of parts around the model with Balloon feature. Front side of the LED low profile light model with numbering of parts is shown in Fig. 4.15 and back side is shown in the Fig. 4.16.

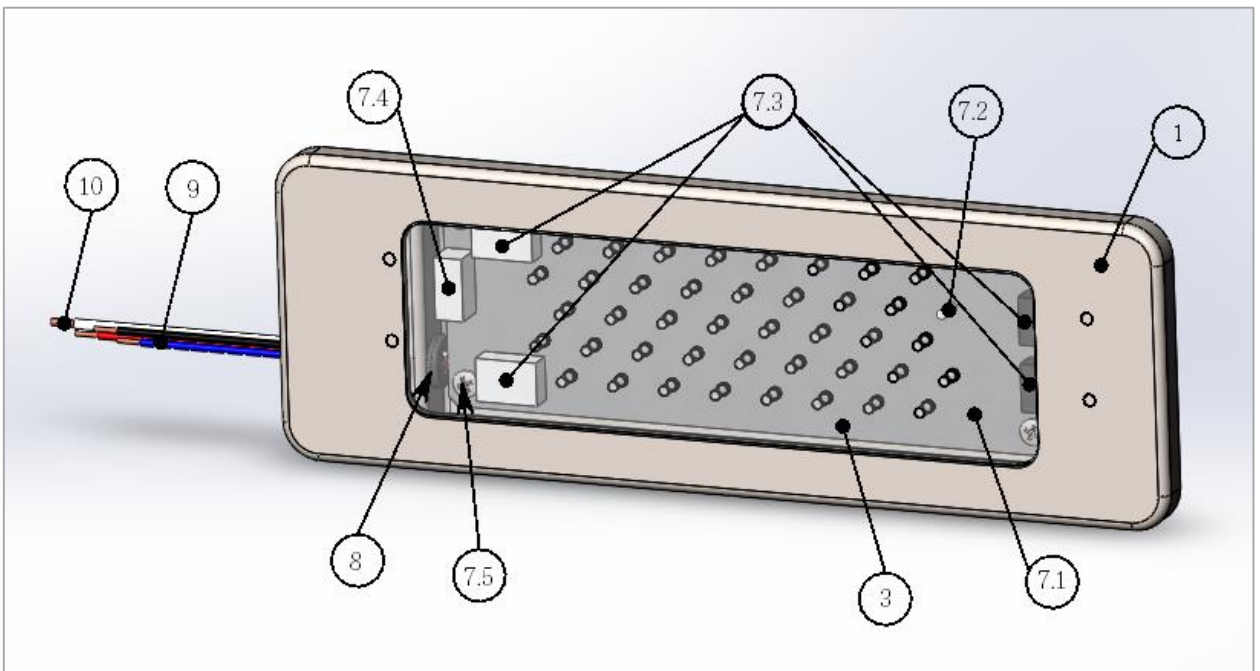


Fig. 4.15 Front side of 3D model of LED lighting with item numbering

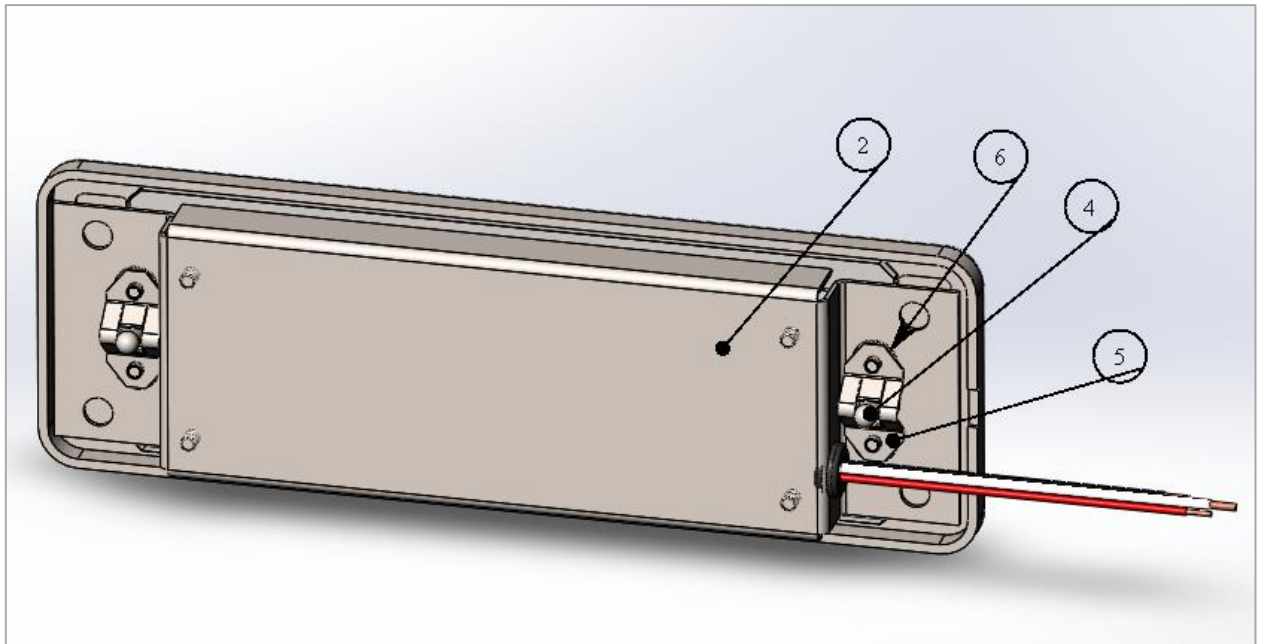


Fig. 4.16 Back side of 3D model of LED lighting with item numbering

By clicking on Design Table feature, I have created an empty table and then filled it with names of model parts, its numbering, part quantity used and materials of parts. Material for every part I have found previously in the standard library of materials in SOLIDWORKS. The received table gives information about the item number, part number or name, material and quantity of parts shown in the table in the Fig. 4.17 .

ITEM NO.	PART NUMBER	Unit	QTY.
1	Front Part	AISI 316 Stainless Steel Sheet (SS)	1
2	Back Part	AISI 316 Stainless Steel Sheet (SS)	1
3	Plastic Part	ABS	1
4	Latch Part 1	AISI 316 Stainless Steel Sheet (SS)	2
5	Latch Part 2	AISI 316 Stainless Steel Sheet (SS)	2
6	Latch Part 3	AISI 316 Stainless Steel Sheet (SS)	4
7	Circuit Board Assembly		1
7.1	Circuit Board ^Circuit Board Assembly	A-Glass Fiber	1
7.2	Diode^Circuit Board Assembly	ABS PC	42
7.3	Capacitor ^Circuit Board Assembly	EPDM	4
7.4	Switch^Circuit Board Assembly	ABS	1
7.5	B18.6.7M - M3 x 0.5 x 8 Type I Cross Recessed OHMS -8S	AISI 316 Stainless Steel (SS)	4
8	Cable Clip	Silicon Rubber	1
9	Insulation	Polyethylene Cross-Linked	4
10	Wires	Copper	4

Fig. 4.17 Design table in SOLIDWORKS

When the table was completed with the data, I have saved it as an Excel document shown in the table in the Fig.4.18. After that, I have closed SOLIDWORKS as it is not necessary to use data from the model but from the table saved in Excel to create a FP report.

ITEM NO.	PART NUMBER	UNIT	QTY.
1	Front Part	AISI 316 Stainless Steel Sheet (SS)	1
2	Back Part	AISI 316 Stainless Steel Sheet (SS)	1
3	Plastic Part	ABS	1
4	Latch Part 1	AISI 316 Stainless Steel Sheet (SS)	2
5	Latch Part 2	AISI 316 Stainless Steel Sheet (SS)	2
6	Latch Part 3	AISI 316 Stainless Steel Sheet (SS)	4
7	Circuit Board Assembly		1
7.1	Circuit Board	A-Glass Fiber	1
7.2	Diodes	ABS PC	42
7.3	Capacitor	Aluminum, EPDM	4
7.4	Switch	ABS	1
7.5	Bolt B18.6.7M	AISI 316 Stainless Steel (SS)	4
8	Cable Clip	Silicon Rubber	1
9	Insulation	Polyethylene Cross-Linked	4
10	Wires	Copper	4

Fig. 4.18 Design table saved as excel document

It is convenient to use table in such a format, as all analysis in fire properties department is made in Excel software manually or by using macros. Such Excel document will be added to 3D system called PDM Smartteam, in the same place as 2D drafts and 3D models of different assemblies and parts. Now it is not needed to open huge 3D models in SOLIDWORKS to make an analysis of definite assembly. It is possible to open excel document, where all dimensions, materials and glues used are listed in one place.

4.5 Connection of the FP report with the Design table

Filled Excel table, which was imported from SOLIDWORKS 3D drawing, could be used for creation of FP report. To import data from Excel document to FP report, I have used the same approach as was used before for importing data from BOM. FP report can be created automatically with the usage of macro in Microsoft Excel. As FP report for such a small assembly is not a standard case, I have created the report without help of macro.

I have created the FP report for LED low profile light on the basis of standard template for FP report. As usually report consists of Introduction, Requirements, Fire Containment Substantiation, Fire Properties Substantiation/ Comparison, Conclusion and Annexes chapters. First chapter should not be changed except of LED light part number. In the chapter 2.2. Fire Properties, fire properties test requirements is provided. The applicability of these test requirements is defined for each specific material configuration and shown in the *Fig. 4.19*. The F06 flammability test used for testing of cables and wires and the F07 flammability test used for testing of the shrinkable sleeve on wires are described.

F06 (60°)	<i>Nomenclature:</i>	Flammability – 60°
	<i>Requirement:</i>	JAR 25.869 (a)(4) and Appendix F, Part I, (a)(3) (ref. AITM 2.0005)
	<i>Test Specimen:</i>	30" (762.0 mm)
	<i>Acceptance Criteria:</i>	<ul style="list-style-type: none"> - Average burn length must not exceed 3 inch. - Average after flame time must not exceed 30 seconds. - Drippings may not continue to flame for more than 3 seconds (average) after falling.
F07 (HST)	<i>Nomenclature:</i>	Flammability – Heat Shrinkable Tubing
	<i>Requirement:</i>	Airbus ABD0031, section 7.1.7, AITM 2.0038
	<i>Test Specimen:</i>	Length of at least 610.0 mm (24")
	<i>Acceptance Criteria:</i>	<ul style="list-style-type: none"> - Average burn length must not exceed 3 inch. - Average after flame time must not exceed 30 seconds. - Average after flame time of drips must not exceed 3 sec.

Fig. 4.19 Flammability tests F06 and F07

As only non-metallic parts must be described in FP report, information such as materials and dimensions of all non-metallic parts must be provided. Using the data from excel table, I have created the separate tables for big and small materials in the chapter 4.3 Material Lists. Where small parts are less than 51 mm x 51 mm x 51 mm (2 inch x 2 inch x 2 inch) or 76 mm x 76 mm x 13 mm (3 inch x 3 inch x 0.5 inch). In the table Material list of big parts of LED low profile light shown in the *Fig. 4.20*, big parts, its part numbers, manufacturer, application and test requirements are described.


		Fire Properties Comparison Report Document no.: 0204197 Revision: NC Date: 3 - May - 2020				
		4.3 MATERIAL LISTS – CUSTOMER SPECIFIC MATERIALS				
The table below identifies all materials that are introduced as part of the customer specific completion kits listed in Table 4.1 and Table 4.2.						
SUB-ASSEMBLY						
ITEM	PART NUMBER	NOMENCLATURE / DESCRIPTION / BUILD-UP <i>(incl. material, finish, relevant dimensions, vendor)</i>	VENDOR / MANUFACT'R	APPLICATION	APPLIC. TEST REQ.	COMPLIANCE
-	0204197-3	Front plastic part, ABS, 10 x 56 x 156	LuminatorAerospace	CLOSET LIGHTING INSTALLATIONS	F06, F07	
-	0204197-7.1	Circuit Board, A-Glass Fiber, 3 x 45 x 130	LuminatorAerospace	CLOSET LIGHTING INSTALLATIONS	F06, F07	

Fig. 4.20 Material list of big parts of LED low profile light

In the table Small Parts list shown in the Fig. 4.21, small parts names, its part numbers, dimensions, quantity used are described.


		Fire Properties Comparison Report Document no.: 0204197 Revision: NC Date: 3 - May - 2020			
		SMALL PARTS LIST			
NO.	PART NUMBER	NOMENCLATURE / DESCRIPTION	DIMENSIONS [mm]	QTY PER (SUB) ASSEMBLY	
-	0204197-7.2	Diode lens, ABS	Ø2,5 x 5	42	
-	0204197-7.3	Capacitor, EPDM	5 x 9 x 13, 4 x 5 x 10	4	
-	0204197-7.4	Switch, ABS	6 x 7 x 13	1	
-	0204197-8	Cable Clip, Silicon Rubber	Ø11 x 5	1	
-	0204197-9	Wires insulation, Polyethylene Cross-Linked	Ø2 x 0,5	4	

Fig. 4.21 Material list of small parts of LED low profile light

Chapter 5 Conclusion states that the non-metallic materials used in construction of the assembly meet the applicable fire properties requirements as set path in this report. Therefore, the assembly is considered safe for production and subsequent installation in Airbus A318 / A319 / A320 / A321 series aircraft.

As a result we see, that the Excel document can be analyzed with the same automatic macro as has been used before, but with already filled table it would be much more easier to do. This way will save a lot of time to preparer, as assemblies usually includes many parts. Moreover, since 3D model is created earlier than 2D drawings, the usage of 3D data for creating Fire Properties report has big advantage as the qualification can be done earlier in project timeline.

To sum up the results of performed work, it is possible to consider new approach of Fire Properties report preparation easier than previous one.

5 Technical and economic evaluation of the implementation of technical change into the 3D system

5.1 Technical and economic evaluation approach

Technical and economic evaluation of implementation of changes is aimed at making improvements and requires the following steps, such as evaluation of the scope for improvements, estimation of costs of its implementation, technical and economic evaluation before and after implementation of the improvements. [51]

With the aim of making an assessment of implementation of improvements to the 3D system, my work consisted of developing a qualitative and quantitative method to evaluate implementation of changes. Our aim is the creation of a FP report based on 3D data instead of 2D. For this aim, I have chosen 5 technical aspects and 5 economic aspects. I have made an evaluation from technical and economic aspect before and after implemented changes and assigned every criteria from 1 to 5 points, where 5 is the best mark and 0 is the worse mark. The results of evaluation in numerical form made in Microsoft Excel are summarized in the table in the *Fig. 5.1*.

Technical aspect		Before	After	Weight Factor	Before*WF	After*WF
1	Quality of prepared report	3	5	5	15	25
2	Complexity of report creation	2	5	5	10	25
3	New software feature implementation	5	1	1	5	1
4	New procedures implementation	5	1	1	5	1
5	Necessity of training	5	1	1	5	1
				Total	40	53
Economic aspect		Before	After	Weight Factor	Before*WF	After*WF
1	Time spent on report creation	2	5	5	10	25
2	Additional cost for software	5	1	1	5	1
3	Time spent on training	5	1	2	10	2
4	Time spent on procedures changes	5	1	1	5	1
5	Time spent on implementation of new features	5	1	2	10	2
				Total	40	31
				Overall	80	84

Fig. 5.1 Technical and economic evaluation results

The technical evaluation consists of 5 criteria. First one is analysis of prepared report quality. As after implemented changes the flaws and errors on drawings will be found faster in Design Tables, the criteria Quality of prepared report got 5 points and before changes got only 3 points. The second criteria was Complexity of report creation, where I assigned 5 points to After changes and only 2 Before, as it became really easy to prepare the report using filled excel table. It does not need to fill thousands rows table with information about assemblies and its parts. The third criteria was New software feature implementation, which means that it is needed to install new plugin (useful additional software) for SOLIDWORKS and create Design Tables in SOLIDWORKS, that was not needed before the changes. The next criteria was New procedure implementation, which means that new handbook with procedures of FP report creation should be written, checked and published in company. The last criteria was Necessity of training, where I assigned 1 point to After changes and 5 Before, as after implementation it requires training to all certification department to create FP report by new approach.

I have assigned weight factor (WF) to all criteria, which helps to indicate importance of each criteria. A weight factor is a weight given to a data point to assign it a lighter, or heavier importance in a definite group. [52] I have assigned 5 points to the first and second criteria, as

quality and complexity of report creation are very important in certification department. To other three criteria I have assigned 1 point, as installation of new software, implementation of new procedures and training will be performed only once and will not require a reiteration. Then I multiplied the weight factors and the coefficients before and after the changes, obtained 40 total points before changes and 53 points after. It means that after implementation of changes it will bring new technological improvements.

The economic evaluation is made firstly by analyzing of time spent for preparation of FP report by traditional approach and new one. It usually takes an engineer approximately 13 hours to prepare FP report for entire galley or stowage, with new approach it will take only 7,5 hours as all materials, glues and dimensions would be already described in excel table. For preparation of FP report for LED low profile light, I have spent only 30 minutes. It would take me twice as much time to prepare the report, if I used the old approach and tried to find all information in BOM and on 2D drawings. That is why I assigned 5 points to After changes and 2 points Before changes. The second criteria was Additional cost for software, where I assigned only 1 point to After changes and 5 Before, as purchase of new plugin for 40 computers is needed. The third criteria was Time spent on training, where I assigned the same points, because it is necessary to conduct training for engineers of the certification department for new approach of creating FP report. The next criteria was Time spent on procedures changes, which means the creation of new handbook with procedures will take time that should be paid. The last criteria was Time spent on implementation of new features, where I assigned 1 point to After changes and 5 Before, because after implementation it requires time of engineers to install new plugin in SOLIDWORKS and create Design Tables for all monuments.

I have assigned the weight factor of 5 points to the first criteria, as time spent on report creation is a very important factor. To the second and fourth criteria I have assigned 1 point, as the price of new software is paid only once and time for implementation of new procedures will be spent one time. For third and fifth criteria I assigned 2 points, as training is important and can be repeated if needed, as well as the handbook can be amended and reissued. Then I multiplied the weight factors and the coefficients before and after the changes, obtained 40 total points before changes and 31 points after. It means that for implementation of changes it requires time and money.

From the evaluation table we can see that approach for report preparation after implemented changes (84 points) is more efficient than before changes (80 points), as total points After changes are more on 4 points than Before.

5.2 Calculation of the time and cost of making technical changes

Any innovation must provide a satisfactory level of improvements for an acceptable cost. It is clear, that each technical improvement is with cost behind, which needs to be evaluated.

The scope for improvements is 2125 drawings for each monument of galleys and stowages, for which Design Tables should be prepared in SOLIDWORKS. As an engineer needs approximately 5 minutes for preparing a single Design Table, it would take approximately 177 hours ($2125 \cdot 5$), which is more than 1 month of work for one engineer.

Training should be performed for 200 people, where 1 hour is needed to train 10 people. So it requires 20 hours to train 200 people. The implementation of procedures changes requires one engineer for 1 week, which is 40 working hours ($8 \text{ hours} \cdot 5 \text{ days}$). The time needed to install new SOLIDWORKS plugin for 40 computers is approximately 7 hours (10 minutes per one computer). Additional cost of software is 100 dollars per computer, which is 4000 dollars. As 1 working hour costs 24 dollars, so implementation time of 244 hours ($177+20+40+7$) will cost 5856 dollars ($244 \cdot 24$). Total cost of working hours and software price is 9856 dollars ($5856+4000$).

On the basis of the detailed results of the technical and economic evaluation, it is possible to say, that necessary technical changes would improve existing working processes. However, as any implemented improvement it requires investments. In the result, the implementation of such approach will show significant economic advantages. The implementation of this approach to all the drawings would allow saving time to FP report preparers and finding the flaws and errors on drawings faster and create qualification earlier.

Conclusion

In this thesis work, the improvement of the methodology of creating a Fire Properties report was proposed. The company Safran Cabin CZ s.r.o. description, its history and field of activity were introduced in the first chapter. Further, the SA ACP project and its characteristics were described.

Later the aviation certification and fire properties qualification issues were studied. The focus was made on fire properties documentation such as JAR- 25 and PS-ANM-25.853-01-R2 international documents, which describe requirements for flammability testing of materials used in the interiors of transport category airplanes.

The creation of a Fire properties report, necessary inputs for its preparation, disadvantages of the current 3D system and needed technical changes to facilitate the automatic creation of Fire Properties reports has been considered.

The 3D model of LED low profile light and Design Table were created in SOLIDWORKS software. Further, the table was imported to Microsoft Excel and connected with Fire Properties report. The description of used technological procedure to enable automatic creation of FP report with the usage of 3D data was described. The resulted approach can be implemented to all the 3D drawings in the 3D system so that it can be used on daily basis by Certification department. The using of 3D data for creating Fire Properties report has big advantage as the qualification can be done earlier in project timeline, then by using 2D, since 3D model is created first and 2D drawings later on.

In the last chapter the technical and economic evaluation of the implementation of technical changes to the 3D system was performed with the help of five criteria from technical and economic aspect and using the weight factor. Evaluation of implementation of new approach to company processes was made from technical and economic aspect with the help of five criteria for each aspect and using the weight factor. The scope for improvements, total cost of working hours, software price the spent time for creation of Fire Properties report before and after changes and cost of making technical changes are defined.

In the result, it will have many advantages but requires time for implementation and also investments. The implementation of the new approach to working processes will eliminate disadvantages, optimize and accelerate work with the database. The task of the work may be considered as fulfilled.

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