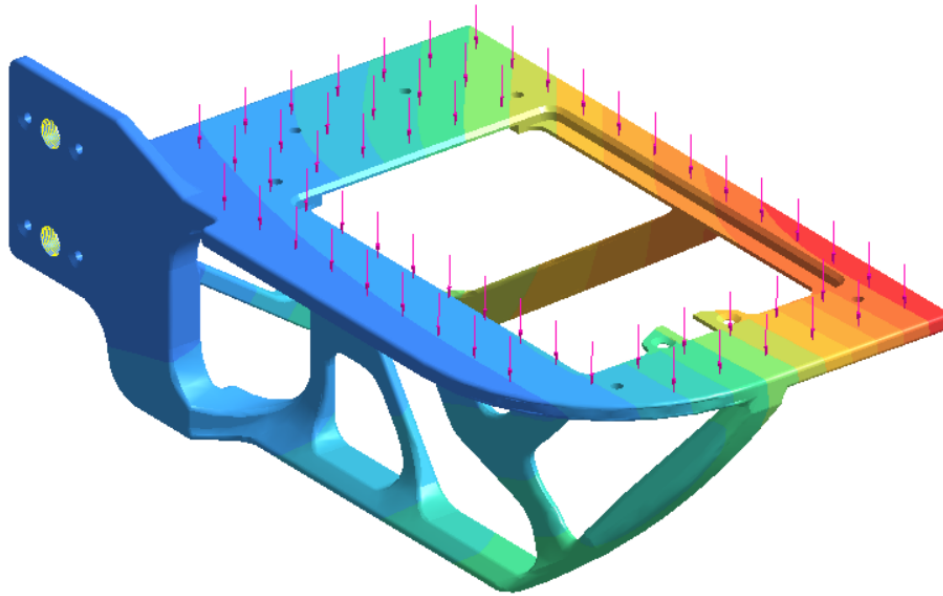




Introduction into Simulation Led Design in Safran Seats GB

Independent Project ACMA6013

Morgan Phillips (2012414)



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David



Declaration

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed.....*Morgan Phillips*..... (Candidate)

Date 12/05/2023.....

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used the extent and nature of the correction is clearly marked in a footnote(s). Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed.....*Morgan Phillips*..... (Candidate)

Date 12/05/2023.....

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed.....*Morgan Phillips*..... (Candidate)

Date 12/05/2023.....

STATEMENT 3

I hereby give consent for my thesis, if accepted, to be available for deposit in the University's digital repository.

Signed.....*Morgan Phillips*..... (Candidate)

Date 12/05/2023.....



Acknowledgement

Firstly, I would like to thank my dissertation supervisor Kelvin Lake for his guidance through the entire process, it has been invaluable, and without the quick, constructive feedback, I would have ceased to complete. Secondly, I would like to thank my employers, Safran Seats GB for providing me with time off to complete the dissertation with full support and guidance. Finally, I would like to thank my family, friends, colleagues and fellow students who, collectively, have supported me through this challenging, but rewarding process.



Abstract

Weight-saving opportunities hold great potential for improving aircraft efficiency, which can benefit airlines and manufacturers such as Safran Seats GB (SSGB). An investigation into simulation software available on the market can enable superior engineering designs compared to conventional product development strategies applied by SSGB. This study investigates two current designs, created as part of a business class seat developed for an A350-1000 aircraft, to shed light on the environmental benefits of a shift from CAD-led design decisions to CAE-led processes. The investigation found a weight saving of 2.72Kg per aircraft could lead to the airline producing 183,872 Kg.CO₂ less over the entire fleet for the suite's lifetime. In addition, the airline could save an additional \$53,040 on fuel due to this small weight saving; with the impact of CO₂ produced by the aircraft being significantly less, the airlines can look to benefit from additional carbon tax savings being introduced in Japan in 2028/29. The results indicate a significant role for simulation software to be harnessed within SSGB in determination to help customers meet its long-term energy use and reduction of greenhouse gas emissions.

Keywords: Topology optimisation, product life cycle, lightweight aircraft components, energy saving, greenhouse gas emissions, carbon-pricing



Glossary

Acronym

AM
CAD
CAE
CC
CM
DDR
DFM
FEA
FOS
GAWR
JAL
KPI
LOPA
LPD
NVH
PAX
PDS
RML
SC
SIMP
SOP
SS
SSGB

Meaning

Additive Manufacturing
Computer Aided Design
Computer Aided Engineering
Critical Characteristics
Conventional Methods
Digital Design Review
Design For Manufacture
Finite Element Analysis
Factor of Safety
Compound Annual Growth Rate
Japan Airlines
Key Performance Indicator
Layout of Passenger Accommodation
Lean Product Development
Noise, Vibrations and Harshness
Passenger
Product Development Stage
Required Material List
Significant Characteristics
Solid Isotopic Metric with Penalization
Standard Operating Procedure
Ship Set
Safran Seats GB

Table of Contents

Declaration.....	ii
Acknowledgement	iii
Abstract.....	iv
Glossary.....	v
List of Figures	vii
List of Tables	viii
1. Dissertation Introduction.....	1
1.1. Introduction	1
1.2. Purpose of this Paper.....	1
1.3. Justification	2
1.4. Aim	3
1.5. Objectives.....	3
1.6. Timing Plan.....	3
1.7. Dissertation Structure	5
2. Literature Review	6
2.1. Introduction	6
2.2. Data Sourcing.....	6
2.3. What is Simulation Software?.....	7
2.4. Optimisation	7
2.5. Advances in Hardware and Software.....	10
2.6. Market Growth	12
2.7. Advantages of Simulation Software.....	14
2.8. Challenges of Simulation.....	16
2.9. CAD vs CAE Led Design.....	17
2.10. Simulation Software Available	18
2.11. Software Comparison.....	21
2.12. Summary	21
3. Work Carried out	23
3.1. Introduction	23
3.2. Software Selected	23
3.3. Case study 1 – Crew Step 1 – 00027200B.....	23
3.4. Case study 2 – Crew Step 2 – 00014061B.....	29
3.5. Summary	33
4. Results.....	34

Introduction	34
Case Study 1	34
Case Study 2	37
Weight/Cost Savings	39
5. Conclusions and Recommendations	41
Future Work	41
Appendices	43
Bibliography	51

List of Figures

Figure 1 - Economic Profit/Loss in 2020 of Aerospace (Bouwer, 2022)	1
Figure 2 - Commercial Aircraft Market Leaders (Mordor Intelligence, 2021)	2
Figure 3 - Project Projection	4
Figure 4 - Project Timeline	4
Figure 5 - Growth of Simulation papers released	6
Figure 6- Sizing Optimisation	8
Figure 7 - Shape Optimisation.....	8
Figure 8 - Topology Optimisation.....	9
Figure 9 - Topology of a Street Bus (Bendsoe, 2003).....	9
Figure 10 - Computational Capacity through History (Roser, 2022).....	11
Figure 11 - Historical Cost of Computer Memory and Storage (Roser, 2022)	11
Figure 12 - CAD/CAE Providers 2023 (iDataLabs, 2023)	13
Figure 13 - CAD/CAE Providers 2011 (Maher, 2012)	13
Figure 14 - Extract of Document NPIE0/W23	14
Figure 15 - Investing More in the early stage of a Project.....	15
Figure 16 - Design Process With and Without Simulation	16
Figure 17 - NPIE01 - Engineering Product Development - Safran Seats GB current process	17
Figure 18 - Quote from Simscale.....	20
Figure 19 - Styling Data for JAL Unity (3A Outboard – SK40608-600)	24
Figure 20 - Development of Crew Step (3A Variant)	25
Figure 21 - Creation of Design Space – Case Study 1.....	25
Figure 22 - Defining Design Space in Inspire – Case Study 1	26
Figure 23 - Support and Distributed Applied Load – Case Study 1	27
Figure 24 - Optimisation Command Window	27
Figure 25 - Faster vs Accurate Results	28
Figure 26 - Converting Results into CAD – Case Study 1.....	28
Figure 27- Styling Data for JAL Unity (4G Inboard)	29
Figure 28 – Development of Crew Step (4G Variant).....	30
Figure 29 - Creation of Design Space – Case Study 2.....	30
Figure 30 - Defining Design Space in Inspire – Case Study 2	31
Figure 31 - Support and Distributed Applied Load – Case Study 2	31
Figure 32 -Converting Results into CAD – Case Study 2.....	32

Figure 33 - PolyNURBS Interface.....	32
Figure 34 - Design Deviation from Topology	33
Figure 35 - Pre & Post Optimisation Comparisons of Displacement – Case Study 1	34
Figure 36 - Pre & Post Optimisation Comparison of Von Mises - Case Study 1.....	35
Figure 37 - Pre & Post Optimisation Comparisons of Displacement – Case Study 2	37
Figure 38 - Pre & Post Optimisation Comparison of Von Mises - Case Study 2.....	37
Figure 41 -Carbon Taxes in Europe (Bray, 2022).....	40
Figure 42 - Email Confirmation of FEA Carried out in Safran Seats GB.....	43
Figure 43 - Fusion 360 Costing.....	43
Figure 44 - Ansys Discovery Compared to Competitors	44
Figure 45 - Creo Simulation Cost.....	44
Figure 46 - Crew Step Installation Drawing.....	45
Figure 47 - Defining Partitions	45
Figure 48 - Required Material List (RML) used within Safran	46
Figure 49 - Inspire 2024-T3 Material Properties.....	46
Figure 50 - SSGB 2024-T351 Material Properties.....	46
Figure 51 - 3D Elements	47
Figure 52 - A350-1000 LOPA	47
Figure 53 - 000014059B Attachment to Composite Shroud.....	48
Figure 54 - Apriori Cost Report Pre Optimisation - Case Study 1	48
Figure 55 - Apriori Cost Report Post Optimisation - Case Study 1	49
Figure 56 - Apriori Cost Report Pre Optimisation - Case Study 2	49
Figure 57 - Apriori Cost Report Post Optimisation - Case Study 2.....	50

List of Tables

Table 1 - Weight reduction in flight hardware.....	15
Table 2 - Software Price Comparison.....	21
Table 3 - Abstract of Key Requirements for Crew Step	24
Table 4 - Case Study 1 - Key Performance Indicators Compared.....	35
Table 5 - Case Study 1 - Von Mises Comparison	35
Table 6 - Case Study 1 - Displacement Comparison.....	36
Table 7 - Case Study 2 - Key Performance Indicators Compared.....	38
Table 8 - Case Study 2 - Von Mises Comparison	38
Table 9 - Case Study 2 - Displacement Comparison.....	38
Table 10 - Weight Saving per Ship Set	39
Table 11 - Fuel and CO2 Savings	39
Table 12 - Factor of Safety (The Engineering Toolbox, 2023)	46
Table 13 - Comparison between Faster Vs Accurate	47
Table 14 - Time Comparison Faster Vs Accurate	47

1. Dissertation Introduction

1.1. Introduction

Simulation software is used throughout all engineering industries to allow companies to evaluate, compare, and optimise alternative designs, plans, and policies. This process has sometimes been different though; a large proportion of the industries still have to transition from conventional Computer-Aided Design (CAD) led decisions. Before simulation software was the norm, companies relied highly on the experience of their designers to produce suitable concepts. Alexander (Alexander, 1964) commented on this subject in 1964 stating, *“Each form in now seen as the work of a single man and its success is his achievement only”*. A designer’s role is now changing rapidly as the advance in technocratic society has caused unsettling uncertainties, unlike previous generations, where there was cultural stability (Lawson, 1997).

Recent advancements in computer systems have allowed all companies to access simulation software to optimise their working procedures to surge their output. The work presented discusses how simulation software has helped evolve the design procedure within product development, which can be utilized to improve the current ones within Safran Seats GB (SSGB).

1.2. Purpose of this Paper

The coronavirus pandemics devastated the aerospace industries; Figure 1 highlights the losses sustained by each sector within the aerospace industry, with airlines taking the most significant impact. More than two years after the pandemic began, green shoots of recovery are emerging, with the demand for new aircraft seating rapidly increasing.

Airlines—with the exception of air cargo carriers—were the biggest destroyers of value in the aviation industry during the first year of the pandemic.

Economic profit/loss by subsector, 2020,¹ \$ billion

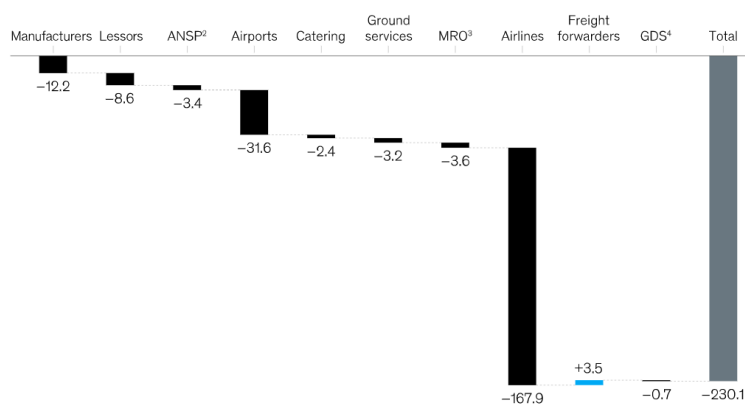


Figure 1 - Economic Profit/Loss in 2020 of Aerospace (Bouwer, 2022)

With the increase in demand for high-end class seats, the workload is growing becoming a challenge for SSGB to maintain the high-quality products produced while successfully meeting rigorous deadlines. With the extremity of recovery from Covid-19 expected to hit in the last quarter of 2023 to the middle quarter of 2024, everything must be done to rationalize processes to allow the teams to meet the objectives successfully.

1.3. Justification

Implementing simulation software in companies is being viewed as more of a necessity now rather than a helpful tool. This technological advance could be harnessed within SSGB to improve design decisions, which in turn should assist in project delivery. SSGB is currently one of the market leaders in manufacturing bespoke suites for airlines. It is forecasted that *“the global aircraft seating market size is projected to grow from USD 6.3 billion in 2022 to USD 8.7 billion by 2027, at a CAGR OF 6.8% from 202 to 2027”* (Markets, 2022). With the demand for businesses to provide high-quality products at low costs, companies will need to adapt to remain relevant.

Commercial Aircraft Seating Market Leaders

- 1 Collins Aerospace
- 2 Jamco Corporation
- 3 Recaro Group
- 4 Safran
- 5 Thompson Aero Seating

*Disclaimer: Major Players sorted in no particular order

Market Concentration



Source: Mordor Intelligence

Figure 2 - Commercial Aircraft Market Leaders (Mordor Intelligence, 2021)

Safran is one of five major players in a populated market (Figure 2), therefore must do everything to improve on deliverables to attract more requisitions. The growth of this market can be attributed to the increasing demand for premium-class seats in aircraft. Customers now demand for In-flight entertainment & connectivity systems to give them a premium travelling experience.

It is not only businesses that have to evolve to meet the desire of consumers; the role of a design engineer is following suit. A designer's role is moving further from the functions originality to those more commonly associated with an all-round engineer. Researchers (Findeli, 2001) & (Lawson, 2006)

highlight how the shift to now focus on the nature of the design practice, tools in the design process, purpose and outcomes of design activity, compared to just physical artefacts in previous generations.

It is, therefore imperative to identify software available on the market to help the designers benefit as the market moves ever closer to fully recuperating. Looking into these tools early on will also help identify the challenges that may arise, which could be damaging with the introduction of simulation software.

1.4. Aim

The aim is to locate a simulation software which can be introduced into SSGB, which designers can operate without the need for in-depth analysis required by Finite Element Analysis (FEA) with the potential to create or adjust a Standard Operating Procedure (SOP) currently used in SSGB.

1.5. Objectives

1.5.1. Objective 1

Demonstrate how bringing Computer Aided Engineering (CAE) forward in the product development stage can make it more effective for SSGB.

1.5.2. Objective 2

Carry out a case study of an existing product within SSGB demonstrating how/if the product could have been improved by using simulation software.

- a) Improvement via weight savings against the target initially given to the product.
- b) Potential fuel savings the airlines could achieve due to weight reduction.

1.5.3. Objective 3

Validate results from the simulation case study with the stress department to gain confidence in the software.

- a) Validation is to be done through FEA analysis on HyperWorks studio, which is the software currently used within SSGB

1.6. Timing Plan

Figure 3 is a Gantt chart, created at the beginning of the project with tasks which was required to deliver a successful project on time. During the creation of the chart, a few tasks would be decided later on in the project if they were required during this stage. These are the creation of SOP, which need much input from all departments for these changes to happen.

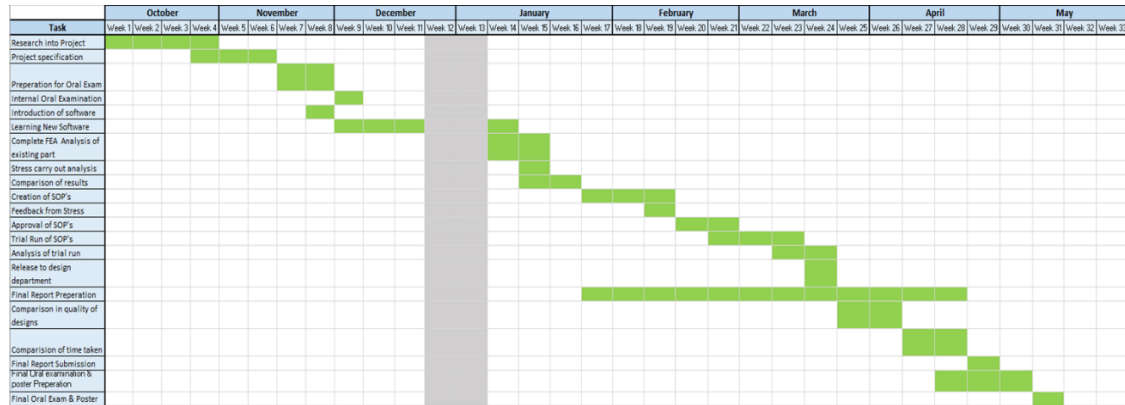


Figure 3 - Project Projection

Figure 4 presents the actual project timeline, the tasks highlighted in yellow on the left-hand side all relate to the creation and release of SOP, which for this project was deemed not feasible due to time constraints with a live production of the JAL product line taking priority. The plan was updated after Christmas compared to Figure 3 due to some complications with sourcing the software from the IT department. Time saved from not creating the SOP was spent within the case studies working with the stress department to understand better what is required from them to complete their analysis.

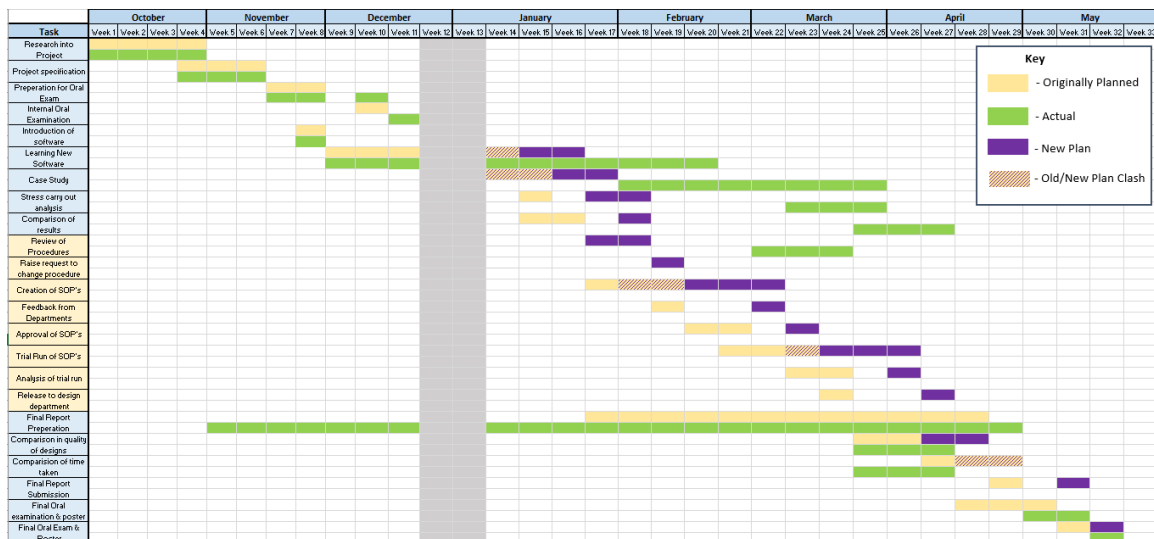


Figure 4 - Project Timeline

1.7. Dissertation Structure

The dissertation is structured in the following way;

1.7.1. Chapter 1 – Dissertation Introduction

An introduction, followed by the purpose of this research paper, with the distinguishing of the author's aims, justification, objectives, and structure of the dissertation.

1.7.2. Chapter 2 – Literature Review

An examination of the published literature surrounding the use of simulation software used within all industries globally and its effects on these industries.

1.7.3. Chapter 3 – Work Carried Out

A review of case studies in SSGB looking examined how simulation software could have affected the designs of previous products.

1.7.4. Chapter 4 – Results

A review of the results obtained during the case studies was completed in Chapter 3 with how simulation software could have affected design decisions.

1.7.5. Chapter 5 – Conclusions and Recommendations

The author concludes the dissertation by summarising all the findings during the report with recommendations they believe could lead to improvements within SSGB processes.

2. Literature Review

2.1. Introduction

Within this chapter, the author will be studying the latest published literature on simulation software and its role within industries using it to obtain a more comprehensive understanding of the topic and how they intertwine. The author will clarify why these bodies of evidence were selected to identify the main advantages, also underlining any challenges associated with implementing simulation software into SSGB. After discovering these findings, the author will then prepare a summary to complete the chapter, which will assist with the work carried out to implement the software into SSGB.

2.2. Data Sourcing

According to the IEEE digital library, between 2014-2017 there were 43,188 scientific research papers published (Abu-Taieh, 2019). On further investigation, Figure 5 shows the rapid growth of journal articles released on simulation topics, all taken from the IEEE Explorer search engine.

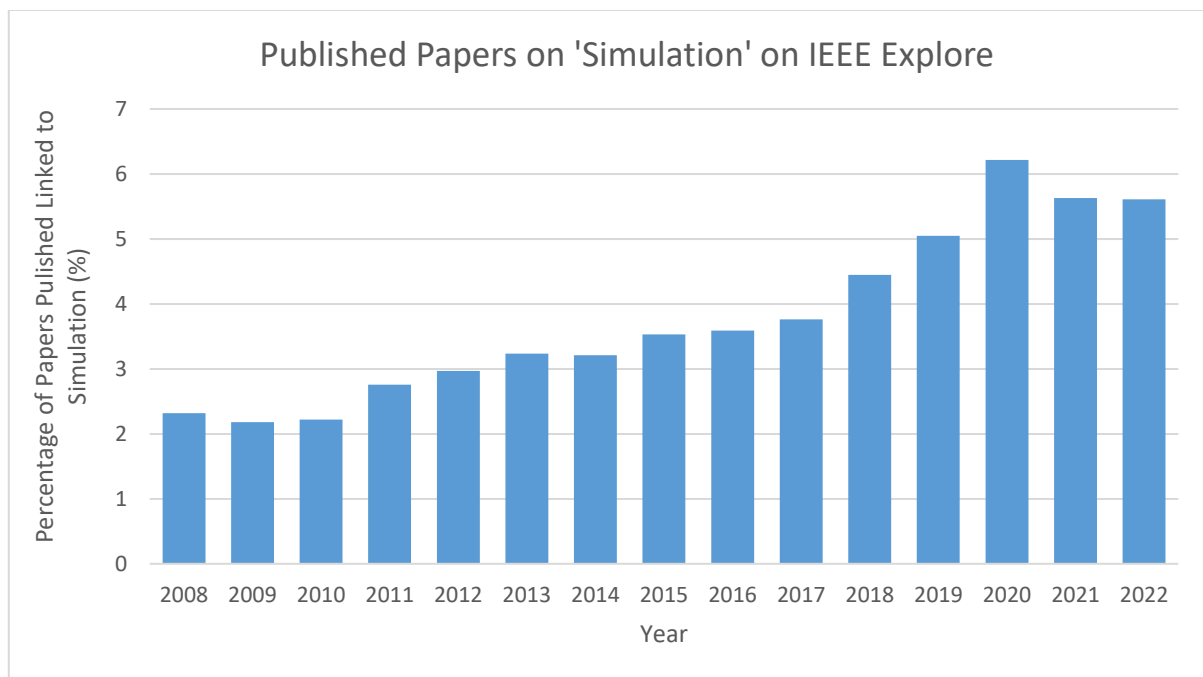


Figure 5 - Growth of Simulation papers released

The growth in simulation papers being published indicates how rich the simulation topic is now with this current generation, with the need to try to utilise it in engineering. With the vast amount of research papers undertaken in the last decade, all information sourced will be modern, furthermore highly reliable.

2.3. What is Simulation Software?

Simulation, also known widely as Computer-Aided Engineering (CAE) is defined as *“the use of a computer to represent the dynamic responses of one system by the behaviour of another system modelled after it. A simulation uses a mathematical description, or model, of a real system in the form of a computer program”* - (Britannica, 2021).

Simulation is a software program that will allow the user to observe an operation through simulation without having to perform the operation physically. As with every instrument used within the engineering industry, there are benefits to using this tool, but there are also limitations to what it can achieve; these shall be discussed further in this report.

Simulation can be used to drive design concepts; it allows engineers to reduce the time spent in the design stage by quickly determining the best possible design concept by utilising the decisive load paths. However, it does not stop there. Once designs have been created based on the concepts, simulation can be used to further optimise the product with techniques talked about in the following sections.

2.4. Optimisation

What is Optimisation? Optimisation is intrinsically tied to human nature, where the need to try to excel is ingrained; this is in all forms of life, not just within engineering. As an athlete, artist, or even a courier, there are some parameters, perhaps time, where the aim is to try to minimize or maximize one or more results such as performance, income, or job satisfaction. This is subject to limitations or constraints, such as physical ability, time available, legal restrictions, or moral codes of conduct.

For example, a courier driver must deliver a certain amount of parcels by the end of the day, no matter how long it takes. The courier driver will look to take the optimal route (minimalist route) to complete their job in the quickest time; as humans, there is the drive to solve a problem in the best way.

This is similar within engineering; a design is optimised to meet weight, cost, and reliability requirements. An optimisation is more than just trying to reduce the weight; it is about maximizing the performance of the material application while minimizing life-cycle cost. CAE technology has advanced to provide tools that can be used for structural design optimisation throughout several design phases. Techniques that attempt to improve mechanical structures can be classified into three categories.

2.4.1. Sizing Optimisation

Size optimisation is widely used to investigate the optimal dimension of cross section parameters for crucial product characteristics. The cross-sectional area defines the cross-section of the truss structure. A simple sizing optimisation problem is sketched in Figure 6 below; it highlights three different cross-section types for specific parts of a fixed truss structure. During the sizing optimisation process, the optimal dimension of each cross-section would be evaluated. The possible result is a structure with a minimal weight that fulfils constraints concerning maximum displacements or stresses.

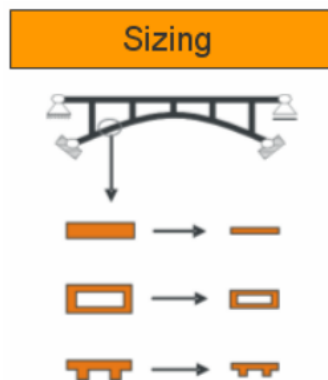


Figure 6- Sizing Optimisation

2.4.2. Shape Optimisation

Shape optimisation refers to procedures that predict a boundary (or shape) of the design domain of the structural/mechanical system to be optimised. Shape optimisation is used in practice for cases where an initial profile already exists, but for a given Finite Element Mesh (FEM), nodes on the boundary are displaced to achieve an objective (like minimizing the stress on the surface, for example).

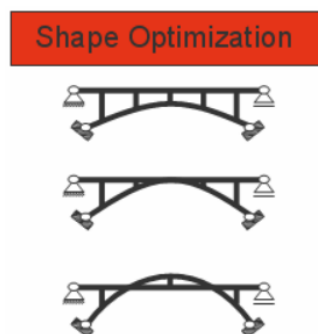


Figure 7 - Shape Optimisation

2.4.3. Topology Optimisation

Topology optimisation is a mathematical technique that spatially optimises the distribution of a material with a defined domain. The pre-established constraints are broken down into three main elements, design variables, the cost/function, and the limitations on the design (Bendsoe, 2003).

Bendsoe and Kikuchi introduced this process in 1988 when they presented a microstructure/homogenization approach to solving topology problems. This theory was further adjusted by Bendsoe to be then identified as the “power law” or Solid Isotropic Material with Penalization (SIMP) approach (Bendsoe, 1989).

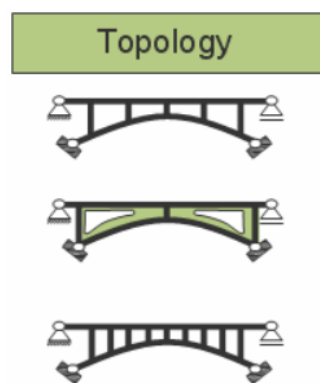


Figure 8 - Topology Optimisation

The methodology over the last decade has become common in all types of engineering, especially within the automotive sector. There have been numerous examples within the automotive industry where material distribution was applied to real-world problems. In the early 2000s, an American council looked into their city buses’ design to try to reduce the amount of carbon dioxide they were producing. They looked into creating lightweight buses, so they hired Altair Engineering to look into the design of the bus to reduce the weight.

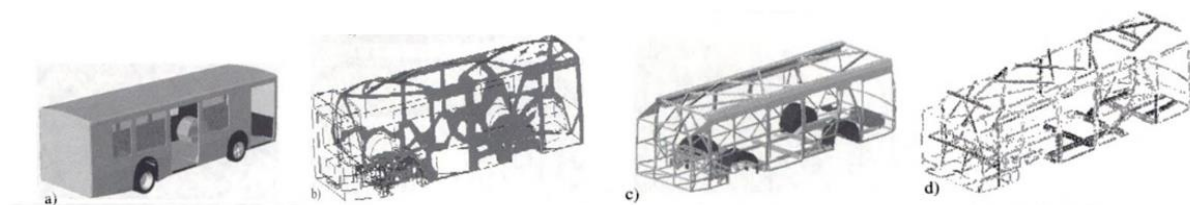


Figure 9 - Topology of a Street Bus (Bendsoe, 2003)

Altair created a space boundary of the size of the current buses the city had, and they made load paths in addition to constraints of actual conditions the bus would experience on daily trips. Topology simulations were run to identify critical load paths, which were used to create a new lightweight frame

(Figure 9) for the bus while still being able to meet the strict regulations in place for public transport (Bendsoe, 2003).

2.5. Advances in Hardware and Software

Advancements in software have led to many CAD packages now introducing topology optimisation into their packages as standard, enabling the designer to use the software as early on in the design process as possible. CAD packages are constantly evolving to try to gain market share as the markets bullishness continues conveying each year. Data exploration carried out by (Technavio, 2021) has predicted, *“The computer-aided design market share is expected to increase by USD 3.28 billion from 2020 to 2025, the market's growth momentum will accelerate at a Compound Annual Growth Rate (CAGR) of 6.41%.”*

A key driver for the rising market is the availability of subscription-based CAD software; this has fuelled the growth of the computer-aided design market in recent years. Recently, the market has started transforming from the original license-based to the subscription-based model as market leaders Autodesk announced they would stop selling permeant licenses (Autodesk, 2022) and offer only subscription-based packages. This shift to subscription-based has allowed CAD vendors to redesign their available products to provide customers with Taylor-made plans to attract more organizations to use their software.

Historically the use of CAD systems with perpetual licenses where there is an initial cost to purchase a license and then an additional annual subscription cost that entitles the owner to all updates along with technical support. These were found to be reasonably expensive, costing many businesses out of obtaining the software with the required tools. With a subscription model, paying a quarterly or annual cost that includes the software, updates and technical support will make it more affordable to smaller businesses.

It is not only the software that is evolving. As humanity advances through the years, technological advancements have become more frequent, allowing us to utilise the full potential of materials. Figure 10 gives a graphical representation of how 500 of the fastest supercomputers in the world have increased since 1993 (Roser, 2022).

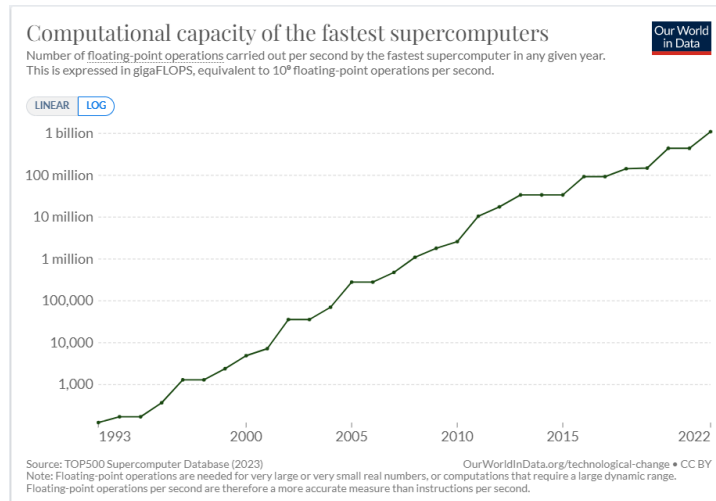


Figure 10 - Computational Capacity through History (Roser, 2022)

While this does not represent the average computer, it highlights the computational capacity to indicate how technology is advancing over the years. With the advancement in technology, including the increase in speed, it would seem logical to think that all of this would cost more. Figure 11 shows how the cost of computer memory and storage has decreased. Avi Greengart, who is the President of one of the most sought-after consumer analysts companies, explained in (Nguyen, 2022) report that *“computer pricing is disinflationary because it adheres to Moore’s Law”* he also added, *“Making those chips smaller creates bigger, better yields, which allows them to actually keep the price the same or lower it with more performance over time”*

Moore’s law is the observation that the number of transistors on a chip doubles about every 24 months; this is just an observation made by Gordon Moore of a historical trend. In 1965 Gordon posited they would double every which they did up until 1975, where he then projected the growth would slow to every 24 months (Burg, 2021).

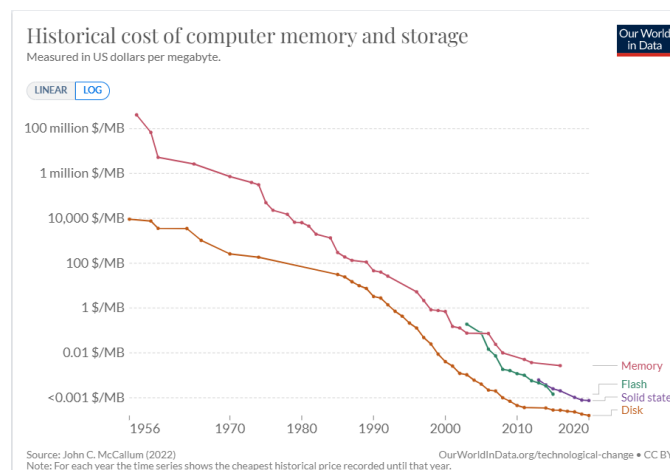


Figure 11 - Historical Cost of Computer Memory and Storage (Roser, 2022)

According to expert research (Zhou, 2020), Moore's Law is estimated to end sometime in the 2020s. This means that computers are projected to reach their limits due to transistors being unable to operate within smaller circuits at increasingly higher temperatures. This will be largely down to the cooling of the transistors; it will require more energy to cool them than the energy that passes through the transistor itself.

As the computer's capacity seems to be reaching its limits, this will leave an opportunity for another technology to surpass it. In recent studies at Stanford, it was found that artificial intelligence is doubling every 3.4 months (Saran, 2019); they measured this by the time required to train a network on cloud infrastructure for supervised image recognition fell from three hours in October 2017 to just 88 seconds in July 2019. All of this means that maybe in the near future artificial intelligence will start to be used in design engineering by looking into ways to create new efficient designs for sustainable future projects.

2.6. Market Growth

The availability of CAD/CAE in the 21st century was undoubtedly aided by the trend of cloud-based CAD/CAE (Bethany, 2017). This was first introduced in 2010 by market leader Solid Works at their 2010 world event (Johnson, 2010). Even though the concept took several years to become a mainstream topic in the CAD industry, this market change helped it to accelerate.

The CAD/CAE market suffered a 23% dip worldwide from, \$6.7 billion in 2008 to \$5 billion in 2009 (Dow, 2010). This was due to the great recession, which was caused by the collapse of the housing market in the US; all industries in all geographies felt the effects of the great recession. The market was expected to recover by 2014, according to the Jon Peddie research conducted in 2010 (Dow, 2010), but it reached \$6.4 in 2010 while increasing to \$7 billion in 2011 (Dow, 2011), showing how highly sort after CAD/CED is within industries.

This growth in the market has now left it highly concentrated, with few players occupying the market share. With 116 CAD/CAE providers on the market, the majority being taken up by three competitors shown in Figure 12. Market research was conducted by Enlyft, which uses sophisticated, patent-pending algorithms to track the use of various Computer-aided Design & engineering products and technologies. The algorithm has found data from 650,398 companies within the US (iDataLabs, 2023).

Computer Aided Engineering & Design 2023

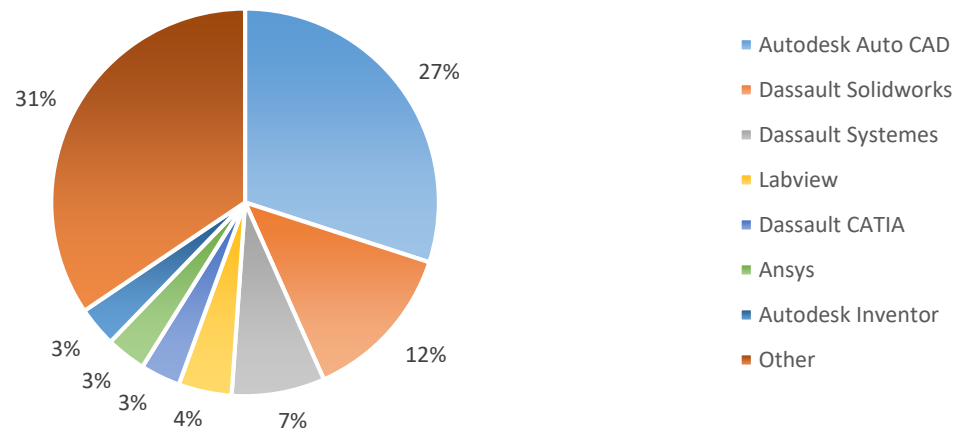


Figure 12 - CAD/CAE Providers 2023 (iDataLabs, 2023)

Compared to the CAD/CAE providers in 2011, the three leading providers have now lost part of their market share (Maher, 2012), and that has dispersed to new competitors in the market, showing smaller CAD/CAE providers are now starting to gain their place within the market.

Computer Aided Engineering & Design 2011

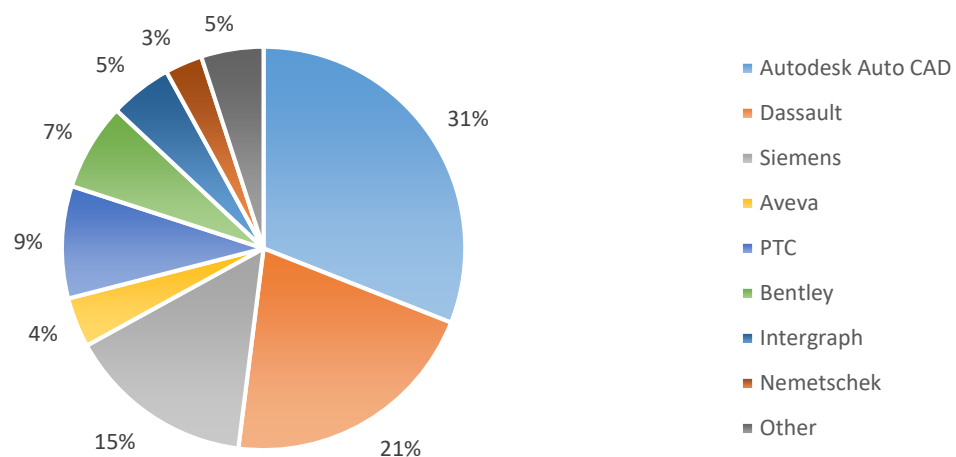


Figure 13 - CAD/CAE Providers 2011 (Maher, 2012)

The growth of software providers, has led to a mandate in society as a whole for more designers (DeAmicis, 2019) looks into how the tech market has influenced the number of jobs for designers over the past ten years. Market research (DeAmicis, 2019) found that the University of California had a 250% increase in demand for designer engineers from employers in technology and design between 2010-2019.

2.7. Advantages of Simulation Software

Computational simulations are becoming increasingly powerful due to the advancement in computational capacity discussed in section 2.5, which allows simulations to be fulfilled faster. When executed correctly, they can provide essential insights into the Significant Characteristics (SC) of potential designs; it is crucial within SSGB to identify the SC and Critical Characteristics (CC) within designs, as they need to be highlighted on production drawings with a control plan in place for them following SSGB process NPIE0/W23 (Figure 14).

SC/CC Call out

CC	Designates critical characteristic monitored per control plan
SC	Designates Significant characteristic monitored per control plan.

SC/CC's shall be called out/indicated on drawings/Cad data by a flag note as shown in Figure 1.

SC callout using flag note symbol -  . CC callout using flag note symbol 

Figure 14 - Extract of Document NPIE0/W23

It is important to remember that simulation is only a valid approach to pre-made concepts to help define and optimise design options; this is not a substitute for creating tangible prototypes as covered (Bonsignore, 2019).

One of the significant benefits simulation software has is that it allows the user to explore unknown scenarios without conducting any physical experiments, which costs money. Chief of digital manufacturing at Rolls Royce, Tim Williams-Wood, explains this in an interview he undertook for Coventry University where he states, *"So, you might have three or four different proposals on how you might change your manufacturing system, and you can try all of those in this risk-free virtual environment and each one might give you different results."* (Williams-Wood, 2020)

Exploring unknown scenarios to define the design in the early stage of the product's life is pivotal as uncertainties, which lead to design changes, create a magnitude of the incurred costs if the initial design is underdeveloped. This can refer back to the rule of ten, where the further an issue moves undiscovered into the late stages of a project, the higher the costs of eliminating it (Dechand, 2016), Figure 15 shows a graphical representation of this scenario.

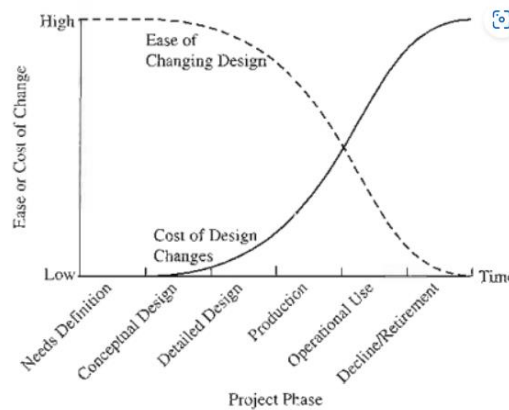


Figure 15 - Investing More in the early stage of a Project

When simulation software is not encouraged in the early design stage of a product, it leads to over-engineering, excessive use of materials, waste in manufacturing operations, and additional usage of resources to maintain or, once the product is in service, re-produce the product. Examples of this can be found in (Orme, 2018), where they looked into three case studies of flight hardware, Star Tracker Camera Bracket, SSTL edge insert & Lunar Lander engine mount. These three existing designs were optimised using topology on Altair HyperWorks 14.0, validated through physical prototypes.

	Case Study 1 – Star tracker camera bracket	Case Study 2 – SSTL Edge Insert	Case Study 3 – Lunar Lander Engine Mount
Weight before optimisation	425g	Unknown	4.0Kg
Weight after optimisation	89g	40% Weight Reduction	2.95Kg

Table 1 - Weight reduction in flight hardware

(Sajid, 2019) Looked into how simulation could assist in decision-making at the initial design stage of product development. In their findings, they discovered that the use of simulation delivered more reliable estimates of savings (in cost), resources, and performance statistics improvements than that are attainable using the proposed Lean Product development (LPD) model.

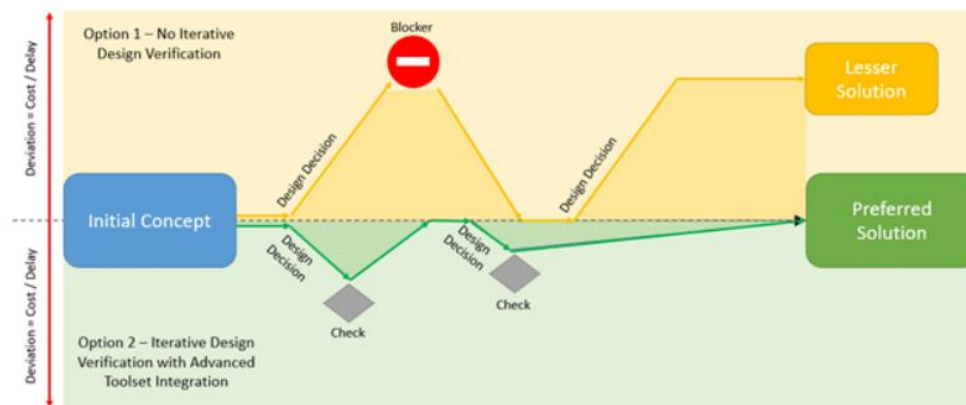


Figure 16 - Design Process With and Without Simulation

The most efficient way to develop a new product is for the process to be linear between the concept stage and the preferred solution. Figure 16 shows the optimal route as the dashed line; each time a design decision is made on a project, the design could move away from the goal (Option 1). Using simulation software as a checking tool integrated into this process will lead to decisions being validated sooner, leading to a more linear design process, as shown in option 2 of Figure 16.

2.8. Challenges of Simulation

There are still challenges to simulation software, which could be one of the main reasons why it has not yet to be adapted within the SSGB design development process.

While there have been recent changes in how available simulation software is, in the shift from license to subscription-based, making it more affordable to businesses, there is still a high cost that could price the small companies out of this tool. Not all simulation providers have completed the change while only offering licenses for their simulation tools; these licenses can cost \$4,000 up to \$20,000 per license. At the same time, subscription-based models range from \$100 to \$1000 per month, depending on the software's capabilities and the number of users in the business (TrustRadius, 2023).

Subject to the hardware being used, simulation can still often require a significant amount of processor power, increasing the time for the simulation to run. Another factor that will have an effect on the time taken to complete the simulation is the complexity of the problem trying to be achieved. It was discussed previously as an advantage to simulation how it can provide answers to a few different scenarios in a short period, this is still true, but sometimes the initial setup can be time-consuming.

The initial conditions input into a simulation defines the initialization of various parameters in the system. They play a vital role in the computing time of steady-state simulations, moreover, play a

more significant role in the case of transient analysis (SimScale, 2022), so defining these parameters can be problematic besides being a time-consuming process for many users.

(Martins, 2022) Research into how boundary conditions need to be defined precisely; otherwise, it can translate into discrepancies in any results obtained from the simulation. The investigation established that *“unrealistic boundary conditions might result in unlikely shearing stresses and depending on the precision aimed, the results can lead to wrong conclusions, sometimes leading to failures.”*

Simulation is not always accurate or precise; simulation does not yield an answer but merely provides a set of the system’s responses to different operating conditions. In many cases, this lack of precision is difficult to measure. With all simulations, there should be some expectation for discrepancies between the simulation results with tested products, but with experience, engineers can use these to refine their simulation systems.

2.9. CAD vs CAE Led Design

Within SSGB, the design process is currently using a CAD-led-based method (Figure 17); this means that a conceptual design is generated using a CAD package and then developed by the designer & team to what they believe is the best design solution. CAE is introduced later on in the design process to verify these results. These results are communicated back to the designer, where modifications are made from the results; this process can iterate several times before the design satisfies the requirements.

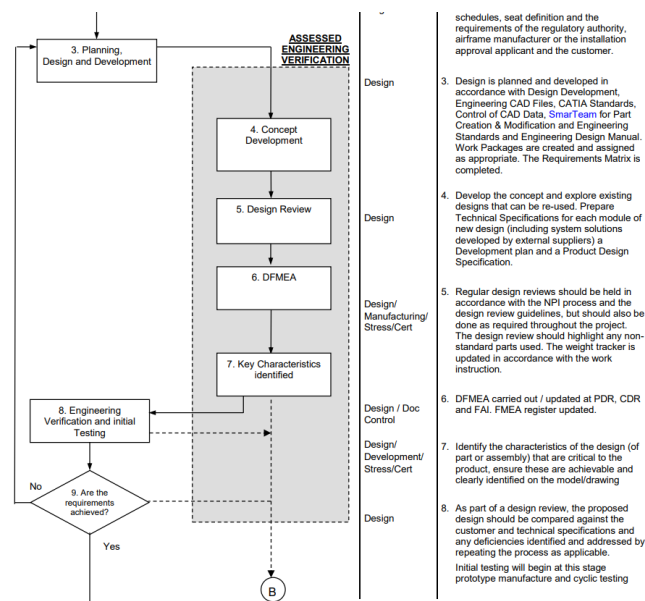


Figure 17 - NP1E01 - Engineering Product Development - Safran Seats GB current process

This discontinuation in the process leads to wastage in the form of lost time as the designer is awaiting feedback from the CAE analysis. The use of CAE in judging the design is essential, as it reduces the number of prototypes required to be built, reducing the product life cycle which was highlighted in previous, sectors.

There are, however, opportunities to reduce the time taken in the development stage; introducing CAE during the conceptual stage will help to make design decisions quicker by providing the designer with more information about their concept.

Ford Motor Company first introduced CAE into the business in the early 1990s, when they were among the leaders in the large-scale applications of CAE in every phase of product development. Since the introduction, the Product Development Stage (PDS) has been shrinking since the early nineties due to the confidence gained in CAE. The tool was used to help in decision-making for all significant attributes such as noise, vibrations, and harshness (NVH); Safety (Crashworthiness); vehicle dynamics; durability; thermal effects; aerodynamic systems; or electrical/electronic applications (Kochhar, 2003).

2.10. Simulation Software Available

With a wide range of simulation software available on the market, as discussed in the previous sectors, it was fundamental that the correct simulation software was selected to be tested within the business. To clarify what testing was currently being carried out within SSGB, Huw Jones, who is head of test & simulations at SSGB, was contacted (Figure 40), where he confirmed that SSGB carries out the following on critical modules:

- Linear Static
- Quasi static non-linear implicit
- Non-linear Explicit

In addition, the use of optimisation routines with the linear static solve:

- Topology optimisation
- Size optimisation

Therefore, the software selected needed to consider these factors; some of the choices considered for the project are highlighted in sectors 2.10.1 to 2.10.7

2.10.1. Autodesk

With this having the second largest market share in 2023, as highlighted in Figure 12, this is the most desirable out of all providers available. Studying the packages available, the most compatible with the

most negligible impact on SSGB would be the Fusion 360 package (Autodesk, 2023). This would cost \$545 (£453) per license per year (Figure 41), offering a range of simulation packages such as Shape optimisation, non-linear stress & Static stress. This package does not seem to provide enough to justify the extra cost as the current package; Catia has more propositions (Scan2CAD, 2021).

2.10.2. Ansys

Ansys again has a large part of the market share for CAD/CAE providers, so it must be considered as a realistic option. On further review, with 90 different packages available, the most suitable one would be the 'Discovery package'. This package has several key features, but only two would be harnessed within SSGB, Structural & modal analysis, and Topology optimisation (Ansys, 2023). This package seems to have considerably fewer core features in a comparison carried out by Capterra to competitors on the market, too (Figure 42), with a cost of \$4500 per license which would make it an expensive asset to the business with seemingly only a few valuable features for SSGB to enhance.

2.10.3. Creo Simulate

Creo simulate is available as a standalone application or as an extension of Creo Parametric, which was a big positive for the choice as the idea wasn't to change the CAD provider to provide a standalone application. This package includes linear static analysis, modal structure analysis, and optimisation tools, which are just a few of the many vital features of the data sheet (Creo®, 2023). The cost of the packages is the only major problem, with licenses costing \$8,110 (£6754) per year (Figure 43) which would put a substantial financial burden on the company if they were to introduce licenses for all the designers in the business.

2.10.4. Simscale

This package is a complete cloud-native system, allowing all designers to have access to this work package through their internet accounts. It will enable the designers to upload any CAD from the Catia platform to analyse them online; and allow the user to collaborate in real-time. With a wide range of products on the platform, it will provide plenty of simulation options for designers to utilize (SimScale, 2023). Costing is broken down into four main packages, which require you to request the price; from the four packages, the 'Team' option would be the most suitable for SSGB, so a request was made for this costing.

Simscale was contacted for a quote on their team's package for thirty users, but not concurrently working, so it has the floating option with ten concurrent users while allowing thirty accounts to have access. The quote returned to \$25,000 per year for the team's option or \$4000 per license.



Figure 18 - Quote from Simscale

2.10.5. Dassault Systemes

Dassault systemes is a package already known to SSGB as Catia V5 and is the primary design package used by all locations globally. With the package being heavily used throughout the business, there could be an opportunity to expand SSGB licenses further to include the Abaqus package. Catia shares a standard interface with Abaqus, which would make it easier for Catia users to pick up any operational process. This could lead to a reduction in any required training; one of the critical features of this package is that it allows you to share results with team members, from anywhere, at any time, using a web browser (Dassault Systemes, 2023).

The Abaqus pricing is unavailable on their website as they provide personalised packages to satisfy each user's needs. A quote from Dassault systemes states that it costs around \$20,000 per year to lease a license, with the cost to purchase a full license coming in at \$31,500, with an annual maintenance fee of \$6000 (Djadoudi, 2023). It is unclear whether this cost is per person or a license for the business, but based on online research, it is believed to be per license.

2.10.6. Star-CCM+

Star-CMM+ is a simulation software package produced by Siemens to bring "automated design exploration and optimisation to the CFD simulation toolkit of every engineer." (Siemens, 2023). Star-CCM+ is primarily used as a computation fluid dynamics software, so there will be limited uses for it within SSG; there are a few features, such as topology optimisation which could be beneficial. For the cost of \$24 per hour, which would equate to \$3600 per month based on 37.5-hour weeks worked within SSGB, this package does not seem to meet the demand which is required within SSGB for the cost it comes with.

2.10.7. Altair

Altair is a well-known company known to SSGB as one of their packages; HyperWorks is currently being used to conduct all FEA work on-site. It is different from the HyperWorks package that is being looked at in this case, though; its sister packages, Inspire and Simsolid, are the packages that have caught the attention of the author. Both these packages have great potential; Inspire allows the designer to have feedback on structural analysis within a few clicks while enabling them the ability to conduct topology optimisation (Altair, 2023). The speed of the feedback is critical, as the aim is to reduce the time spent during the development stage; nonetheless the accuracy of the results is vital and needs to be considered.

The Simsolid package is integrated into the Inspire package providing the structural analysis; it is possible to download the Simsolid package as a standalone with any optimisation tools. SSGB is currently paying Altair £1545 per license per year with annual maintenance of £315; there is no additional cost to use the Inspire or Simsolid packages, with training material also available online included in the price.

2.11. Software Comparison

	COST PER LICENSE (PER YEAR)	COST BASED ON 30 LICENCES (PER YEAR)
AUTODESK	£453	£13,590
ANSYS	£3909	£117,270
CREO SIMULATOR	£6754	£202,620
SIMSCALE	£3,522	£22,025
DASSAULT SYSTEMES	£28,082	£842,460
STAR-CMM+	£34,659	£1,039,770
ALTAIR	£1,545	£46,350

Table 2 - Software Price Comparison

2.12. Summary

The author has gained a well-informed understanding of simulation software's effects on designers within engineering, reflecting on the published literature featured to access both the opportunities and threats it poses.

One of the revolutionary benefits of simulation software is meshless software, which allows the designers to gain rapid results without having to do traditional meshing of components within FEA. However, contrary to this, those producing these simulations must still have sufficient education to

ensure accuracy (2.7); the importance of investing early on in the design stage is highlighted throughout the literature reviews where the rule of ten is repeatedly mentioned.

Another significant advantage to simulation software is the ability to test multiple variants in different environments rapidly while having no impact on the cost; the only other way this would be possible would be to create prototypes. This increases the product's life significantly and increases manufacturing cost; while prototyping is essential to any product development minimizing the amount spent on prototypes is necessary.

The figures from several simulation providers have been discussed in Table 2 with assumptions based on 30 designers having access to simulation to start within the business; this could increase or decrease depending on the business needs. Some of these costs have been taken from third-party sources, so they could change once the number of required licenses has been determined.

3. Work Carried out

3.1. Introduction

In this chapter, the author discusses how simulation software was used within SSGB by carrying out case studies of previous designs, which did not use simulation software in the design decisions, and how that has influenced the product.

3.2. Software Selected

With a vast amount of simulation software on the market, as discussed in (2.10), choosing which one to try was difficult, but the decision was based on the availability of the software. Simsolid and Inspire are available due to the Altair package being purchased by SSGB for the HyperWorks package, which is used within the stress department. With no additional cost, along with the software being known to the business, there should be no issues with the availability of this software.

3.3. Case study 1 – Crew Step 1 – 00027200B

3.3.1. Background

JAL Unity was a project which commenced at the end of 2020 at SSGB; the business had secured a contract with Japan Airlines (JAL) to deliver thirteen shipsets of 54 business class seats to be fitted on their brand new A350-1000 aircraft, which Airbus were manufacturing. With the production of these business class suites due to start in the summer of 2023, the designs are now at a mature enough stage to review how they could have been improved with simulation software.

As the author was part of this design team, which helped to deliver specific modules on this project, it has been decided that carrying out a case study on these designs would be beneficial as the author has a good understanding of the design, but they would be able to further progress their skills in product design & development.

3.3.2. Product

The product selected for this analysis was the crew step; this is quite a simple design compared to other larger modules on the suite plays a more significant role than previous designs. This product was required to stow electrical kill switches, which could be accessed by the flight attendants at any point to isolate any electrical issues. The design development was undertaken with a list of requirements provided by key stakeholders along with the styling data (Figure 19), which is defined beforehand with SSGB and JAL.

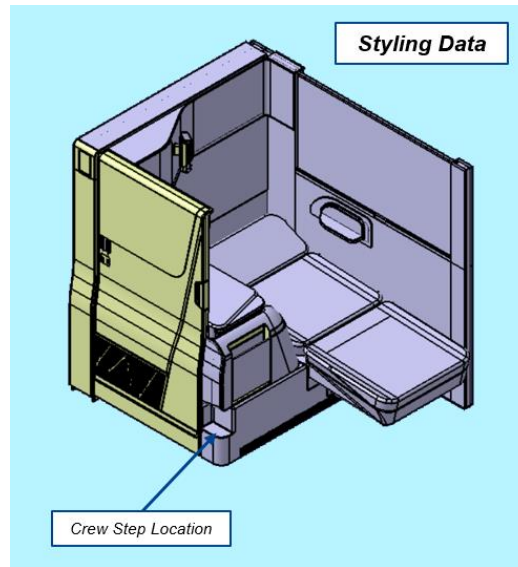


Figure 19 - Styling Data for JAL Unity (3A Outboard – SK40608-600)

Req ID #	Source Document Title	System Requirement Statement
WT-651	JAL J-unity Weight tracker 39114-008	Applicable to all suites: The crew step must NOT exceed a maximum weight of 0.5kg
AIB-479	AIB Passenger Seats Module Frame Specification	The flight attendant step shall resist Ultimate loads of 1330 N (300lbs) applied for 3 s downward and evenly distributed without detrimental permanent deformation.
AIB-480	AIB Passenger Seats Module Frame Specification	The seat, in-flight seat/seat furniture design shall ensure that any portion of capable being used as a step by passengers or attendants shall withstand a downward load of 1360N without permanent deformation. Further design shall support hand luggage, per person 9.1kg (20 lbs) under consideration of crash loads
RM - 7	JAL J-Unity Certification Risk Tracker	Abuse load test: Crew step must withstand 1300 N distributed load applied downwards
CTP - 19	SSGB Cyclic Test Specifications	To simulate the in-service loading conditions of a flight attendant step: the flight attendant step and supporting structure shall withstand a cyclic load of 174 lbf for 31,500 cycles, as per CTS-17, Issue 03
DVP - 26	JAL-Unity Certification DVP	Abuse load Test: Crew step must withstand 1313 N download applied (distributed)

Table 3 - Abstract of Key Requirements for Crew Step

Table 3 highlights just a few of the requirements in the crew step which had to adhere to; the foremost ones highlighted for this case study are the weight and stress requirements, as these are two main areas in which it believed software simulation would benefit SSGB. The importance of weight saving is highlighted in the (Dynatech, 2014) article, where they highlight how reducing the weight of aircraft leads to better fuel efficiency (reduced CO₂ emissions) and lower costs. Another study by United Airlines in 2017, found that a weight saving of just 28 grams by printing their in-flight magazine

on a different type of paper led to saving 643,000 litres of fuel across their whole fleet, with \$290,000 a year savings (Martin, 2018).

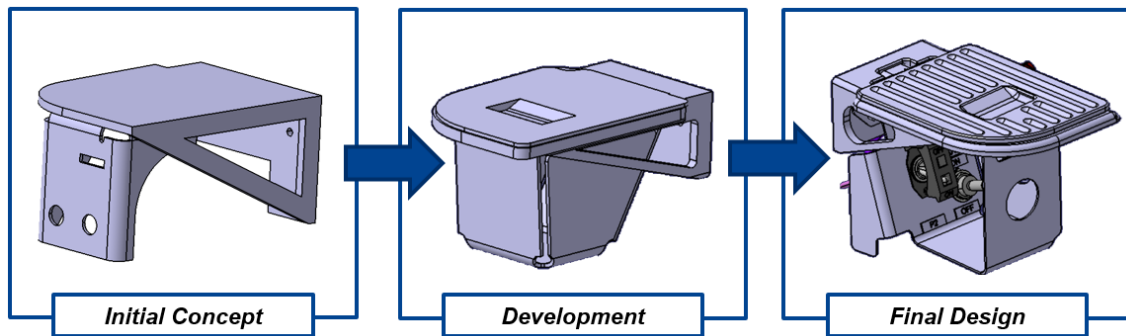


Figure 20 - Development of Crew Step (3A Variant)

Figure 20 highlights the significant developments of the crew step over its product life; between the three stages, shown numerous design reviews, DFM sessions and stress analysis were carried out to help progress the design to a mature stage. Any weight-saving exercises conducted, were down to the designer's experience and any feedback received from production engineers.

3.3.3. Design Space

Picture 1 in Figure 21 shows the released design for the crew step bracket; this is the necessary attachment to the composite shroud where the load will travel through. The second picture shows the bracket being re-engineered back to a basic shape so that the topology optimisation has a vast design space to choose the best load path. To reduce the optimisation time, the design space was further defined in Catia V5 (Image 3) to remove the front area of the design space as access to the panel, which attaches to the crew step is required. Figure 44 shows the installation drawing for the crew step, which demonstrates the bracket attached to the underside.

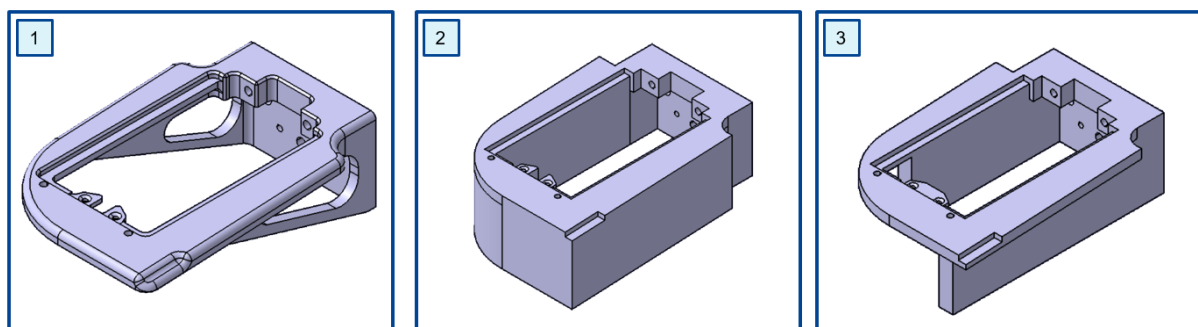


Figure 21 - Creation of Design Space – Case Study 1

Once the design space was defined in Catia V5, It was uploaded to Altair Inspire, where further work to the design space was required. The three attachment holes at the rear of the bracket are a crucial feature, which must not be modified, so a 3mm partition (Figure 45) was created around them to

avoid any changes in this area. The top profile was also identified as an area that could not be modified due to interfaces. Figure 22 shows the areas that the defined areas are design spaces with non-design space regions.

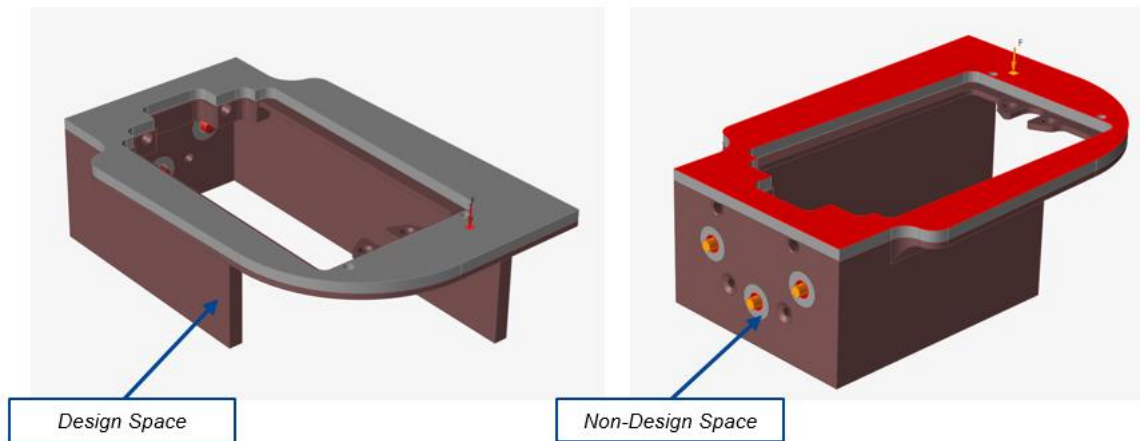


Figure 22 - Defining Design Space in Inspire – Case Study 1

3.3.4. Material Selection

The material selected for the bracket is Aluminium 2024-T351; the selection of materials has been limited within SSGB in recent years due to the introduction of a project called 'One Safran'. The project aims to standardise the use of materials and fasteners used globally across all sectors within Safran (Figure 46). The material selected on Inspire for the optimisation was Aluminium 2024-T3 (275 MPa) (Figure 47), which has a slightly less yield strength compared to the 2024-T351 (290 MPa) (Figure 48); this is not of great concern, though, as the material is softer which would provide a more prominent Factor of Safety (FOS) in the results. The density of the material is the same both on the Required Material List (RML) and on Inspire database, meaning any mass savings should be highly relatable.

3.3.5. Supports, Loads & Constraints

With any topology optimisation, there are three main elements, input parameters, objective functions & constraint functions (Nagy, 2017). The design space has been defined in sector 3.3.3; for the optimisation to fully understand what it is trying to achieve, it needs to know where the product is supported and the forces it will be exposed to. So the support is the three holes at the rear of the bracket where it attaches to the composite panel via three 10/32 fasteners. The distributed applied load is taken from the Airbus requirements highlighted in Table 3; for this case, a 1360 N distributed load is applied downwards (Figure 23).

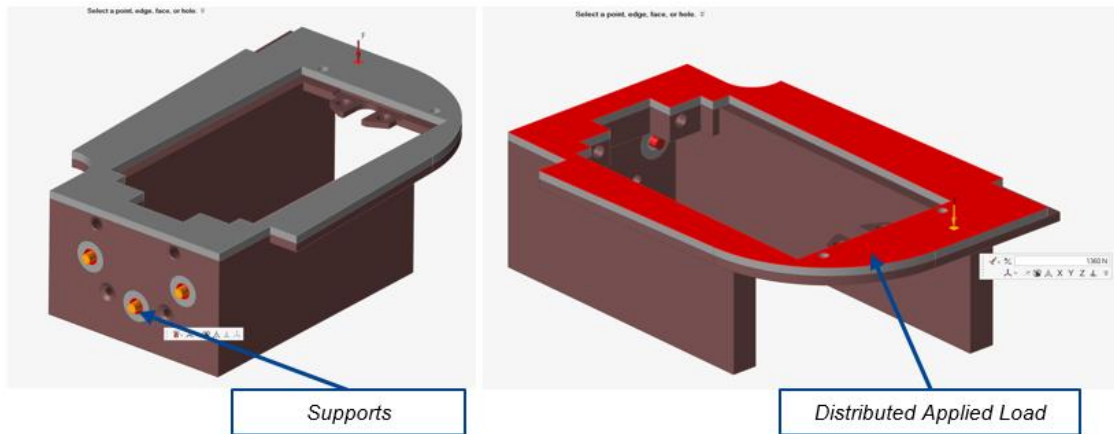


Figure 23 - Support and Distributed Applied Load – Case Study 1

With all the input factors now definite, the two remaining elements to define for optimisation is the objective followed by the constraints. Inspire provides the option for three purposes, maximise stiffness, maximise frequency, or minimize mass; these objectives will vary from design to design depending on what the designer is trying to achieve. In this case, the author tries to reduce the mass of the bracket; one of the constraints used for this topology was for the bracket to have a minimum factor of safety of 1.5, which was determined by using Table 12.

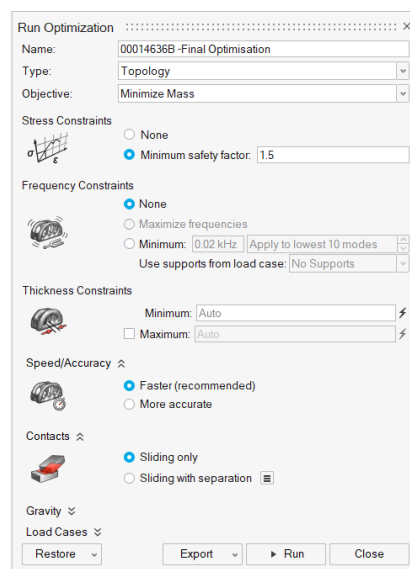


Figure 24 - Optimisation Command Window

3.3.6. Faster Vs More Accurate

Figure 24 presents the options for 'Faster' or 'More accurate' optimisation; this changes the mesh between Tetra 1st order (Linear Tetra 4) and Tetra 2nd order (Parabolic Tetra 10). Results of first-order Tetra analysis and optimisations are stiffer (self-stiffening effect) but more conservative regarding the FOS (Figure 49). The second order is more accurate, but it will take much more resources for the computation, so this might want to be avoided except for the first the final analyses. The difference in

the accuracy is ~5% to ~10% (depending on models); the difference in computation time can be between 1 hour to 10 hours for optimisations (Altair, 2018).

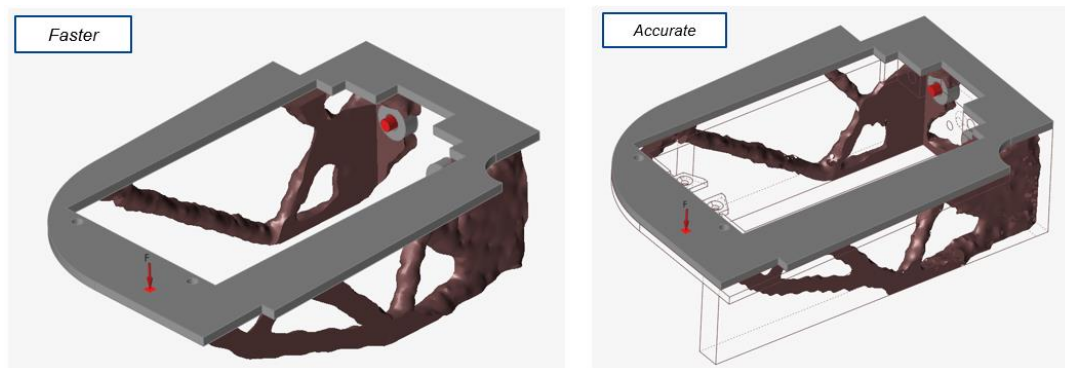


Figure 25 - Faster vs Accurate Results

Figure 25 highlights the difference in the results between the two-optimisation methods; the accurate method produced 100% compliance, while the faster technique only managed 96.1% compliance shown in Table 13. While the compliance is not 100%, the mass of the faster optimisation is slightly less (123.6g) compared to the accurate technique (133.4g). Also, taking into consideration the time taken for both optimisations is shown in Table 14; to run using the faster process seems the most suitable on this case basis.

3.3.7. Results into CAD model

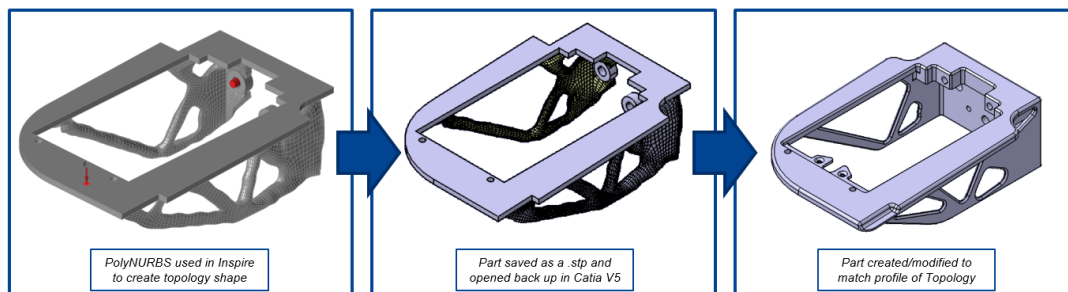


Figure 26 - Converting Results into CAD – Case Study 1

The topology results were transformed into PolyNURBS, a feature in Inspire, discussed further in section 3.4.5. This was extracted as a .stp. file to be loaded into Catia, where the surface could be extracted to create the basic shape; furthermore, development was carried out with radiuses and any cut-outs defined. Radiuses have been kept the same where possible to try to reduce the cost of production, which is one of the factors talked about in (HUBS, 2023), where they highlight 14 key points to reduce the cost of CNC milling operations.

3.4. Case study 2 – Crew Step 2 – 00014061B

3.4.1. Background

The background of this case study is the same as that discussed in section 3.3.1, where the author talks about being part of the design team in charge of delivering 13 shipsets of the business class suite to new customers JAL.

3.4.2. Product

The product has been heavily discussed in section 3.3.2, where the author discusses the intended use of the product; this case study has the exact requirements as the first one, highlighted in Table 3. There are variations from this case study to the first one, though, to comply with the complete Layout of Passenger Accommodations (LOPA), there must be different crew step variations (Figure 50). Conforming to the complete LOPA modules require different variations as styling data, attachment points, and suites size differ. It is vital that, where ever possible, the commonality is kept between product variations, as this leads to higher forecast errors, excessive inventory for some products, and shortages for others. Higher manufacturing costs due to required processes, materials, changeovers, and quality assurance methods (Lee, 1994).

(Stalk, 1993) Traced numerous problems faced by Japanese car manufacturers back to excessive product proliferation, so to mitigate these issues during the development stage of the crew step for JAL, variations were kept to a minimum by designing the crew step to comply with as many of the suites as possible.

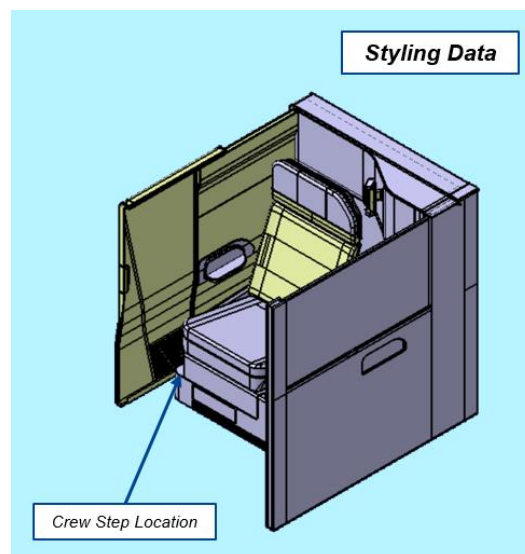


Figure 27- Styling Data for JAL Unity (4G Inboard)

Figure 27 shows the styling data of one of the inboard suite's with the location of the crew step highlighted; this varies from Figure 19 as the attachment methods needed to be modified, as the composite panel was running parallel with the direction of the crew step not perpendicular to it.

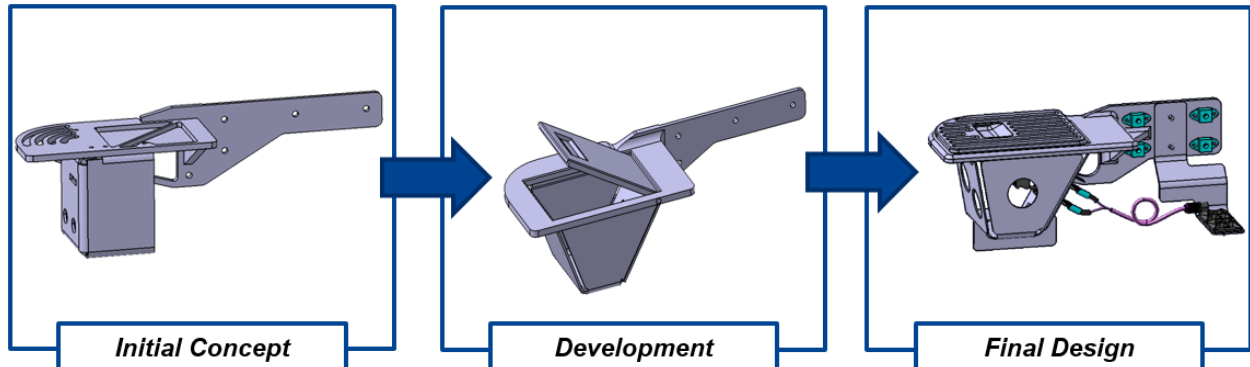


Figure 28 – Development of Crew Step (4G Variant)

Figure 28 shows the development of the inboard crew step; the door guide has defined the attachment holes. As there is already a through hole in the composite, the decision was taken to utilise these attachment points. This would reduce inserts required in the composite shell while the door guide and crew complement each other to increase the strength of the composite structure as they both act as stiffeners for it in a high-stress area.

3.4.3. Design Space

Picture 1 of Figure 29 details the released design for the second variant of the crew step bracket used on the JAL business class program. Like the bracket in case study 1 this is the necessary attachment to the composite shroud, but the attachment is dissimilar to case study 1, where the attachment is adjacent to the downward load, which has a different effect on the component. The bracket does not have a rear wall support to help reduce the deflection of the bracket, like in case study 1, during the design process to try to mitigate any deflection the distributed load can cause. Stiffeners followed by supports were included in key areas, highlighted during an FEA analysis of the first concept produced during the Digital Design Review (DDR).

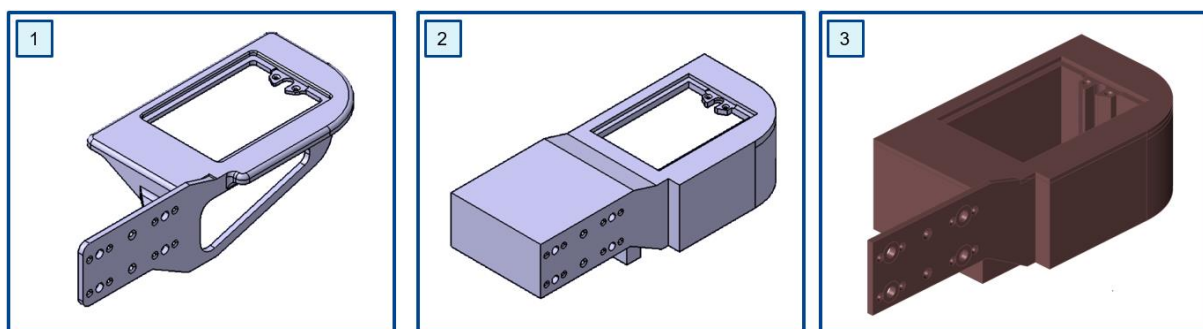


Figure 29 - Creation of Design Space – Case Study 2

The exact process used for case study 1 was undertaken for case study 2, where the space envelope was initially designed in Catia (Image 2 of Figure 29); the maximum area where the topology could occur was highlighted. This area was developed to where the area to define which load paths are required most; Image 3 in Figure 29 was the final space boundary defined for the topology study.

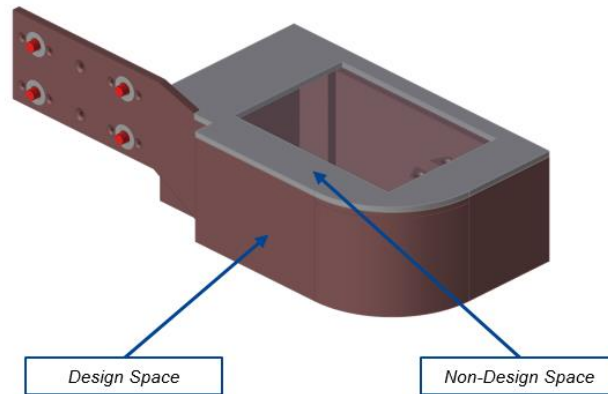


Figure 30 - Defining Design Space in Inspire – Case Study 2

The design space and the non-design space, has been defined in Figure 30, where the attaching holes to the composite have a 3mm non-design space around them, as these positions cannot move due to assembly issues. The top profile is characterized as a non-design space as the vac form tools which create the covers to go around the crew steps have been manufactured, and the cost to scrap these is too great.

3.4.4. Supports, Loads & Constraints

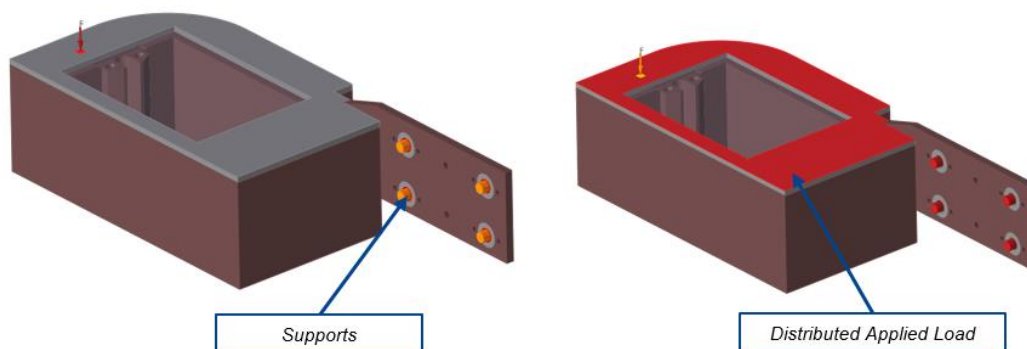


Figure 31 - Support and Distributed Applied Load – Case Study 2

The loads and supports have been outlined during the first case study; these are pre-defined by Airbus requirements in which the crew step has to withstand a maximum of 1360N without any plastic deformation. The plastic deformation of aluminium 2024 T-351 is 290MPa according to SSGB

supplier's information shown in Figure 46; the table provides material properties for designers to know the constraints of the material to consider during their design. Plastic deformation will start to occur at 290MPa; this is when permanent distortion transpires in a material when it has been subjected to tensile, compressive, bending, or torsion stresses that exceed its yield strength which causes it to elongate, compress, buckle, bend, or twist (Pfeifer, 2009)

The loads and supports have been applied to non-design spaces as referring to (Inspire, 2023) manual, which states this as a general rule when conducting analysis. The connections for the supports have yet to be edited for this optimisation, due to design being a low-risk area of concern; if the software is to become mainstream within SSGB, these properties can be explored more in higher-impacted areas, such as meal tables.

3.4.5. Results into CAD model

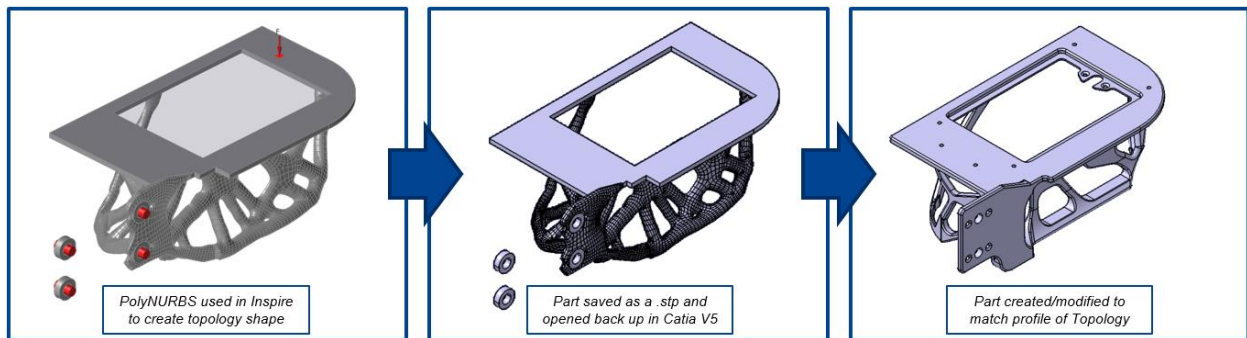


Figure 32 -Converting Results into CAD – Case Study 2

The optimisation was undertaken on Inspire, which took 22 minutes and 13 seconds to complete; the topology optimisation produced the shape in the left image of Figure 32. The form was then taken off the topology by running PolyNURBS, a feature on Inspire to transform the analysis into a .stp. file. The PolyNURBS can be controlled by adjusting their quantity and the curvature; the figures used for the optimisation are shown in Figure 33. Reducing the number of PolyNURBS faces will increase the size of the PolyNURBS cages but will capture less detail. In general, the fewest number of PolyNURBS faces still capture the geometry.

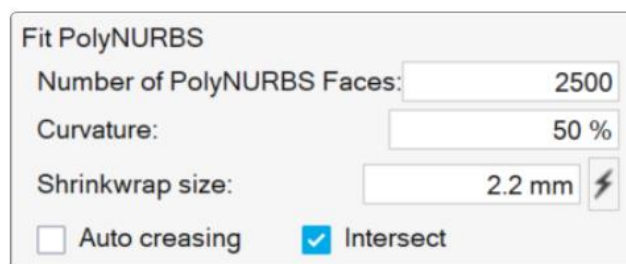


Figure 33 - PolyNURBS Interface

The design between the topology results and the Catia part are slightly different; looking at the few areas highlighted in Figure 34, there are some of the load paths missing. This is due to the topology just being used to inform the design and not fully control it as discussed in section 2.7 where (Bonsignore, 2019) talks about simulation not being suitable for creating tangible prototypes but to be used as a tool.

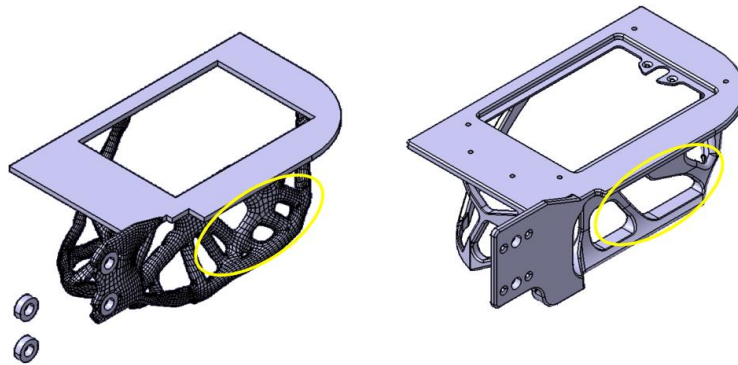


Figure 34 - Design Deviation from Topology

3.5. Summary

Within this sector, the author explored two current designs, which are currently being manufactured as part of JAL business class suites for A350-1000 aircraft; these designs underwent 18 months of development with limited simulation input and only designer-based knowledge verified by limited prototypes.

These case studies looked into how the crew step design could have used simulation software early on in the design process to define the optimum stiffness-to-weight ratio while utilizing the least amount of material. Over four months, the author was able to source the software with the help of the IT department in SSGB to download the simulation package. This software was trialled to understand its capabilities, with the interest of how it can be utilised within SSGB at the forefront. With online learning material, which was included in the license cost, two case studies could be conducted to re-design support brackets with the aim of reducing the weight.

The aim to reduce the weight comes its impact on airlines' CO₂ emissions; any additional weight saving helps the airlines save money on fuel and tax, which they endure. While this does not directly impact the savings on SSGB, it attracts new business from new airlines to SSGB. The ability to provide airlines with lighter suites compared to competitors is a huge factor in this industry, with a very competitive market, as discussed in sector 1.3; securing new contracts is vital for SSGB to prosper.

4. Results

Introduction

In this sector, the author looks into the savings obtained from the analysis carried out during sector 3 of the report; the author investigates how any weight savings obtained from the two case studies can impact the airlines. These studies can be presented as evidence to future clients to support why SSGB is one of the leading seat providers worldwide.

Case Study 1

This case study looked into the support bracket for crew step 00014636B, utilized in 28 PAX of the 54 suites on the LOPA; once the design was finalised in Catia V5 the data was loaded into three different packages. The motive for analysing the same design in three other software packages is for verification; as discussed in sector 1.5.3, the results obtained need to be verified by the stress department to gain confidence that this software is appropriate for use.

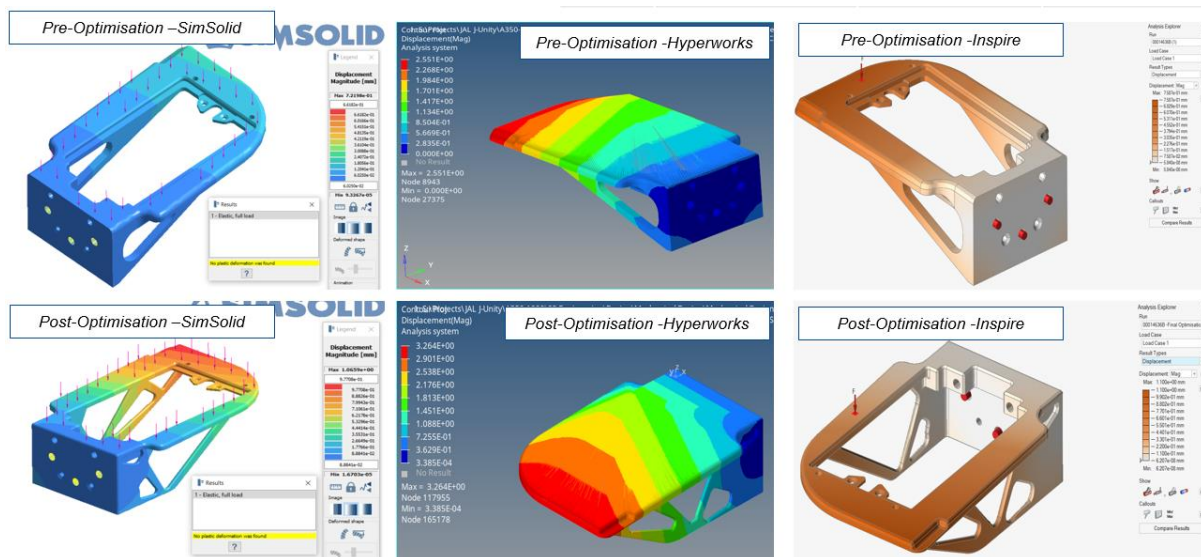


Figure 35 - Pre & Post Optimisation Comparisons of Displacement – Case Study 1

Figure 35 & Figure 36 show the pre and post optimisation models loaded into the packages, one presenting the displacement and the other presenting the Von Mises that occurred when the required load is applied (1360N) to the design. The first key aspect looked at was the Von Mises to make sure that plastic deformation hadn't occurred as this would have caused the design to fail according to requirement AIB-479 highlighted in Table 3.

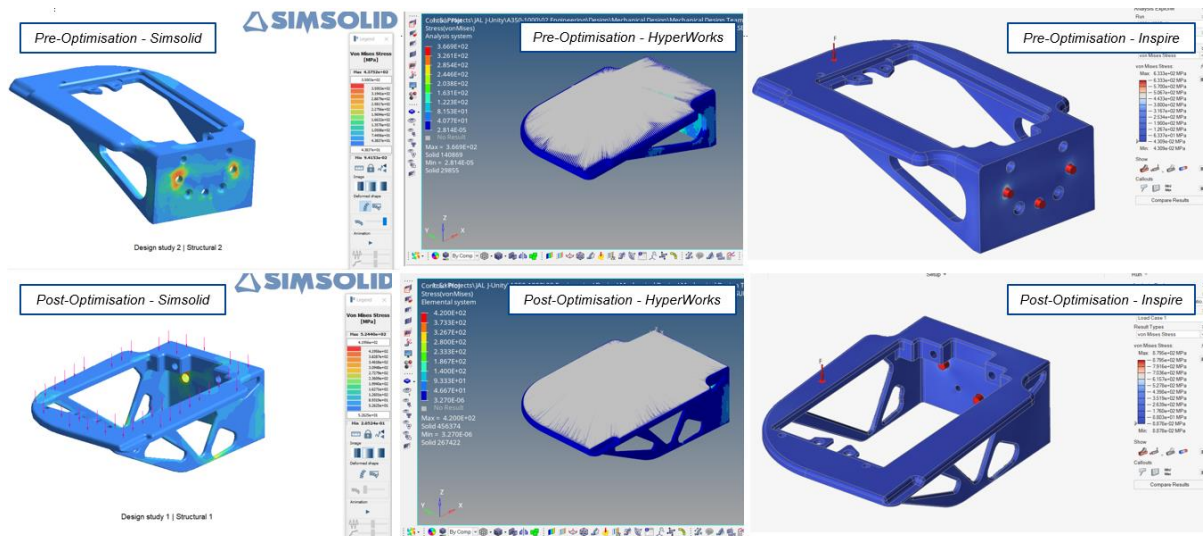


Figure 36 - Pre & Post Optimisation Comparison of Von Mises - Case Study 1

Comparing the three analyses shown in Figure 36, there is a correlation between the high and low-stress areas, which provides us with confidence. HyperWorks is a known software to the business with designs proven in physical prototypes using this software; any results that correlate back to this software can be deemed to have some credibility.

	Pre-Optimisation	Post-Optimisation
Weight	0.21Kg	0.15Kg
Cost	\$66.68 (£53.36)	\$82.05 (£65.65)
Stress Analysis (Von Mises)	4.3752e+02 MPa	5.2440+02 MPa
Labour Time (S)	4,193.65	4,176.48
Cycle Time (S)	4,161.60	4,147.00
Batch Setup Time (Hr)	8.24	14.57

Table 4 - Case Study 1 - Key Performance Indicators Compared

Table 4 highlights the Key Performance Indicators (KPI) between the pre and post-optimisation; while the mass of the crew was significantly reduced, which was the aim of the case study discussed in 1.5.2, the cost of the machining has increased slightly.

	Von Mises (MPa) SimSolid	Von Mises (MPa) HyperWorks	Von Mises (MPa) Inspire
Pre Optimisation	4.376 e+02	3.669 e+02	6.333 e+02
Post Optimisation	5.244 e+02	4.200 e+02	8.795 e+02

Table 5 - Case Study 1 - Von Mises Comparison

Table 5 presents the max Von Mises results from the three different software; while all boundary conditions were kept the same, the results are different in each software; the main reason for this would be the mesh during the analysis. Simsolid and Inspire are meshless and do not require any input from the user to define it, whereas HyperWorks, the mesh, was characterised by an engineer in the

stress department when they conducted the analysis. (Liu, 2013) Paper looks into the effect of mesh size and density on the accuracy of results, so the belief, in this case, is that the mesh size used in the simulation software packages has defaulted to a different size used by the FEA department.

It is easier with experience in FEA to understand the mesh size; if the mesh is too coarse, the generated answers may more accurate that they are. Conversely, if the mesh is defined too fine, the simulation will take much longer to run without substantially improving accuracy.

	<i>Displacement (mm)</i> <i>SimSolid</i>	<i>Displacement (mm)</i> <i>HyperWorks</i>	<i>Displacement (mm)</i> <i>Inspire</i>
<i>Pre Optimisation</i>	7.22mm	2.55mm	7.59mm
<i>Post Optimisation</i>	1.07mm	3.26mm	1.10mm

Table 6 - Case Study 1 - Displacement Comparison

It was essential to measure the displacement of the design before and after the optimisation took place as it was necessary for stiffness in the part was retained while reducing the mass of the step; more weight could have potentially been removed from the design as the Von Mises results show the low amount of stress on the material. This could have affected the displacement of the crew step; displacement in this area was required to be kept to a minimum due to the products intended use; any movement in the design could cause the user to slip from the step.

Case Study 2

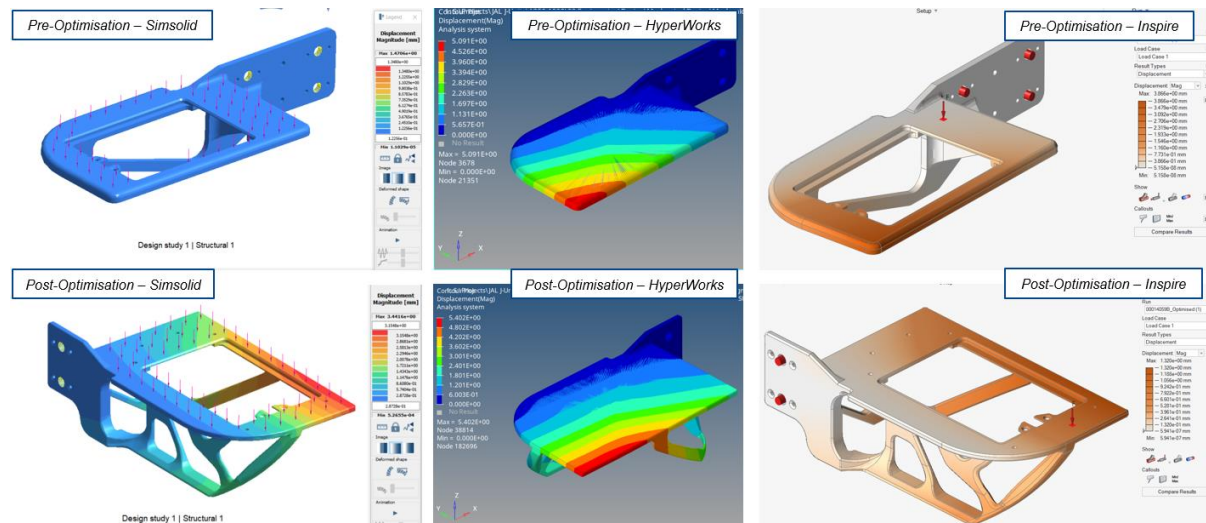


Figure 37 - Pre & Post Optimisation Comparisons of Displacement – Case Study 2

While the exact parameters have been applied in both studies, the results obtained are expected to be wildly dissimilar; due to the attachment points in the composite panels constraining the design possibilities. With no rear support wall for the distributed load to disperse through, the design will require more support to mitigate any displacement from the applied load. Reviewing Figure 37, there is a correlation between all the results, with what is expected to see. The side with the least resistance (support) is put under the most strain leading to the greatest deflection area.

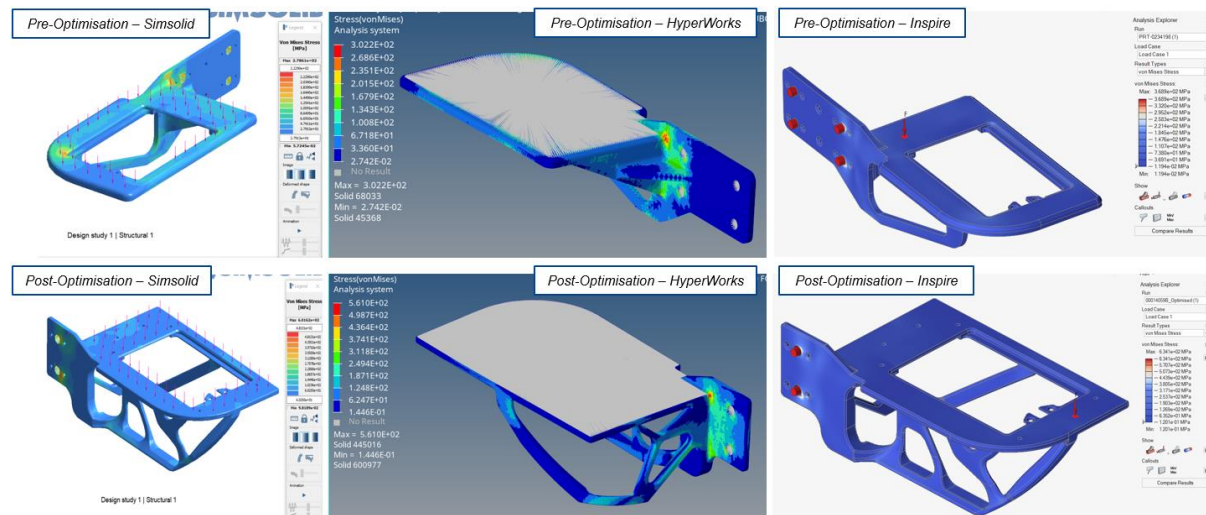


Figure 38 - Pre & Post Optimisation Comparison of Von Mises - Case Study 2

As discussed in 3.4.5, the topology results were used as a template of where the critical load paths will be when the distributed load is applied under these circumstances; initial glances of all three software highlight similar higher stress areas. However, these areas do not seem of great concern though as the Von Mises presents a maximum of 5.610×10^2 MPa, which is just 2% of the material's capabilities

before plastic deformation takes place. While the correlation suggests a good case for the accuracy of the results, the analysis conducted by Apriori (Figure 54 & Figure 55), highlighted an area of concern when using topology analysis for milling components.

	<i>Pre-Optimisation</i>	<i>Post-Optimisation</i>
Weight	0.24Kg	0.2Kg
Cost	\$81.46 (£64.57)	\$104.15 (£82.55)
Stress Analysis (Von Mises)	3.002 e+02	5.610 e+02
Labour Time (S)	1,439.38	2,470.16
Cycle Time (S)	1,416.47	2,446.41
Batch Setup Time (Hr)	4.55	10.72

Table 7 - Case Study 2 - Key Performance Indicators Compared

The complexity of the shape produced leads to set-up time and cycle times drastically increasing; which leads to overall cost increases. Money is not saved in terms of material when it comes to topology due to the billet size starting the same; however, much material is removed. To see the full potential of the money-saving Additive Manufacturing (AM) needs to be implemented, (Huang, 2016) looks into the potential emissions savings due to the material efficiency of AM compared to the Conventional Method (CM).

Reviewing Table 7, it is clear to see the extent of increase in the batch set up and labour time for each of the crew step brackets has drastically risen, so whereas the aim was to reduce the time during the product development, it may not have as impacted as first predicted.

	<i>Von Mises (MPa) SimSolid</i>	<i>Von Mises (MPa) HyperWorks</i>	<i>Von Mises (MPa) Inspire</i>
Pre Optimisation	2.786 e+02	3.022 e+02	3.689 e+02
Post Optimisation	6.016 e+02	5.610 e+02	6.341 e+02

Table 8 - Case Study 2 - Von Mises Comparison

	<i>Displacement (mm) SimSolid</i>	<i>Displacement (mm) HyperWorks</i>	<i>Displacement (mm) Inspire</i>
Pre Optimisation	1.4706 e+00	5.091 e+00	1.320 e+00
Post Optimisation	3.4416 e+00	5.402 e+00	3.866 e+00

Table 9 - Case Study 2 - Displacement Comparison

Table 8 & Table 9 highlight the figures extracted from the software's results; while these results are not equivalent, they are very close to each other with a tight correlation, which could be used as a factor of safety by SSGB designers.

Weight/Cost Savings

To get a whole perspective of the extent of the weight savings, it was best to calculate in terms of shipsets, as it can then be used to calculate the potential fuel savings over the product's lifetime. These savings will be an essential selling factor for SSGB when pitching new concepts to potential clients. Table 10 shows the total weight savings per shipset to be 2.72Kg from these two design changes in crew steps, referring back to (Martin, 2018), where the saving of just 28g per shipset led to \$290,000 savings per year.

	<i>Weight per shipset – Pre Optimisation</i>	<i>Weight per shipset – Post Optimisation</i>	<i>Saving per Shipset</i>
Case Study 1 (28 Brackets)	5.88kg	4.2Kg	1.68Kg
Case Study 2 (26 Brackets)	6.24kg	5.2Kg	1.04Kg
Total per Shipset (54 Brackets)	12.12Kg	9.4Kg	2.72Kg

Table 10 - Weight Saving per Ship Set

Having discussed the potential weight savings with the weights department within SSGB, they were able to provide a weight-saving calculator, which they had produced from taking information from (Aerospace Technology Institution, 2023). SSGB had to offer critical data relating to the aircraft's body type, Flight utilisation followed by the current fuel price at the time undertaken, \$2.79/gal (Jet-A1-Fuel, 2023).

	<i>Case Study 1</i>	<i>Case Study 2</i>	<i>Potential Savings</i>
Weight Saving/PAX	0.06Kg	0.04Kg	
\$ Value/AC/Year	\$252	\$156	\$408
\$ Value/AC/Lifetime of Suite	\$2,520	\$1,560	\$4,080
\$ Value/Fleet/Lifetime of Suite	\$32,760	\$20,280	\$53,040
CO₂ Saving/AC/Year	873.6 Kg.CO ₂	540.8 Kg.CO ₂	1,414.4 Kg.CO₂
CO₂ Saving/AC/Lifetime of Suite	8,736 Kg.CO ₂	5,408 Kg.CO ₂	14,144 Kg.CO₂
CO₂ Saving/Fleet/Lifetime of Suite	113,568 Kg.CO ₂	70,304 Kg.CO ₂	183,872 Kg.CO₂
CO₂ Tax Saving/AC/Year	\$20.62	\$12.76	\$33.38
CO₂ Tax Saving/AC/ Lifetime of Suite	\$206.17	\$127.63	\$333.8
CO₂ Tax Saving/Fleet/ Lifetime of Suite	\$2680.20	\$1659.17	\$4,339.37

Table 11 - Fuel and CO₂ Savings

From the information provided to ATI, they can provide figures for the cost of block fuel burnt, the increase in block fuel burnt per flight, also the level of CO₂ emitted per aircraft per year. The CO₂ tax saving is based upon the current UK tax carbon rate shown in Figure 39; this is due to Japan not indicting any carbon tax when the investigation was undertaken. The fleet size, in this case, is considered 13 as by contract, this is the minimum required to be ordered by JAL, but it does have the

potential to go up to 35 shipsets. The lifetime of the suite was set to 10 years also, as this is the warranty period for the most extended components built into the suite.

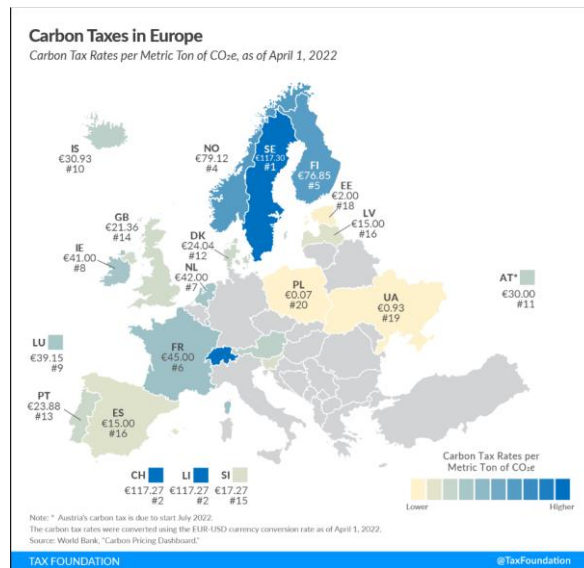


Figure 39 -Carbon Taxes in Europe (Bray, 2022)

Table 11 presents the critical figures that customers will take significant consideration, highlighting the savings which they could endure if these design changes were carried out during the product development. As previously mentioned about the tax saving the cost was based on a UK carbon price due to Japan currently not having a carbon tax, but this is not for long though, as in December of 2022, the Japanese government proposed to introduce a carbon-pricing scheme 2028-29 (Obayashi, 2022). The carbon-pricing scheme will require companies to bear the burden of CO₂ emissions, which will come in two formats, the first being a levy on the company followed by emissions trading between companies.

5. Conclusions and Recommendations

This project aimed to demonstrate how simulation software could be introduced into SSGB to allow the designers to get structural feedback on the design without requiring the in-depth analysis that FEA require. It is possible to produce improved products while at the same time reducing the development time. This has been achieved through the use of the software Inspire where design envelopes have been created, allowing for topology studies to indicate to the author the critical load paths to consider when designing. It has been demonstrated how these designs created on unfamiliar software to SSGB can produce results that correlate with software heavily used within the business.

The simulation software, however, does have limitations. To successfully implement simulation software into the design process, one of the most fundamental inputs to these models is the material properties. It has been demonstrated in Chapter 3 that there are differences between the values published by SSGB manufacturers and those used on the software; these maybe could be adjusted to align with SSGB values to see if the correlation between the software Improves. While the weight of the components was reduced, the satisfaction was lessened by an increase in the machine cycle time, which caused the cost per part to rise. These costs could be overcome with a further adaptation in SSGB, which would go well with the introduction of simulation software, Additive Manufacturing (AM); while this is partially used to create prototypes or production jigs within SSGB, it has not been fully introduced into products yet.

Future Work

In terms of future work that could be carried out by SSGB as a result of this research could be;

1. Look into AM with the trial of printing out the new designs created by the topology studies. This manufacturing process will enable SSGB to fabricate complex designs while keeping costs relatively low due to minimum wastage of material during the process. Having design flexibility would allow for part consolidation by designing assemblies with multiple components as a single product; this will help to drive for a light-weighting design.
2. While this has only been carried out on two simplistic designs, conducting a more extensive case study over the full JAL BC suite would be interesting to see what the overall weight saving could be if most parts were optimised through simulation software. With larger modules like the meal table or privacy screen, these areas could see the most significant weight saving due to the heavier brackets required to reduce deflection.
3. To manufacture the new design concepts created to test them physically, any results obtained can be analysed with the simulation to look for any correlation.

4. Fully incorporate simulation software into the design process for one project to see the impact it has on;

- The overall weight of designs compared to previous projects
- The speed in which the maturity rating reaches 90% in MER 5 checklist SST-DEV-012-2
- Production cost
- Stress analysis reports if there is a reduction in design iterations between the design and FEA.



Appendices

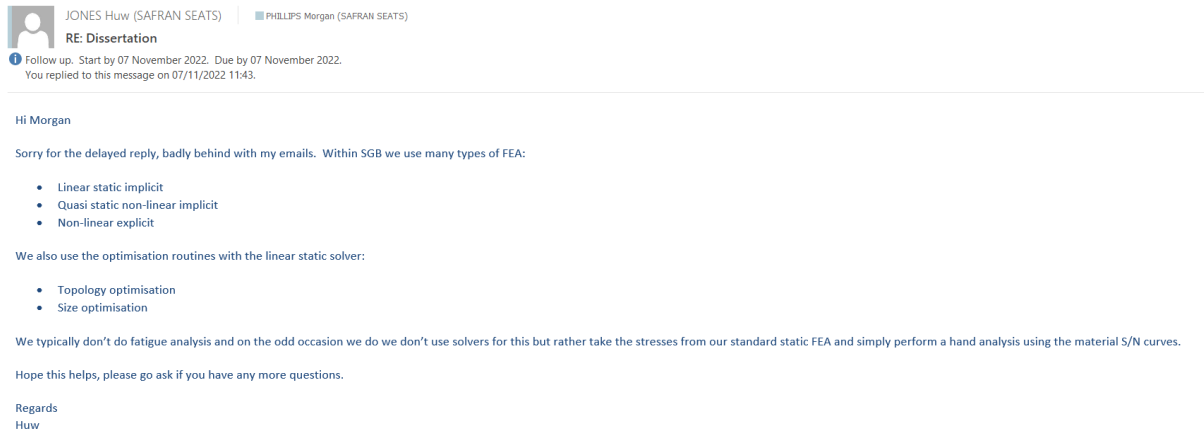


Figure 40 - Email Confirmation of FEA Carried out in Safran Seats GB

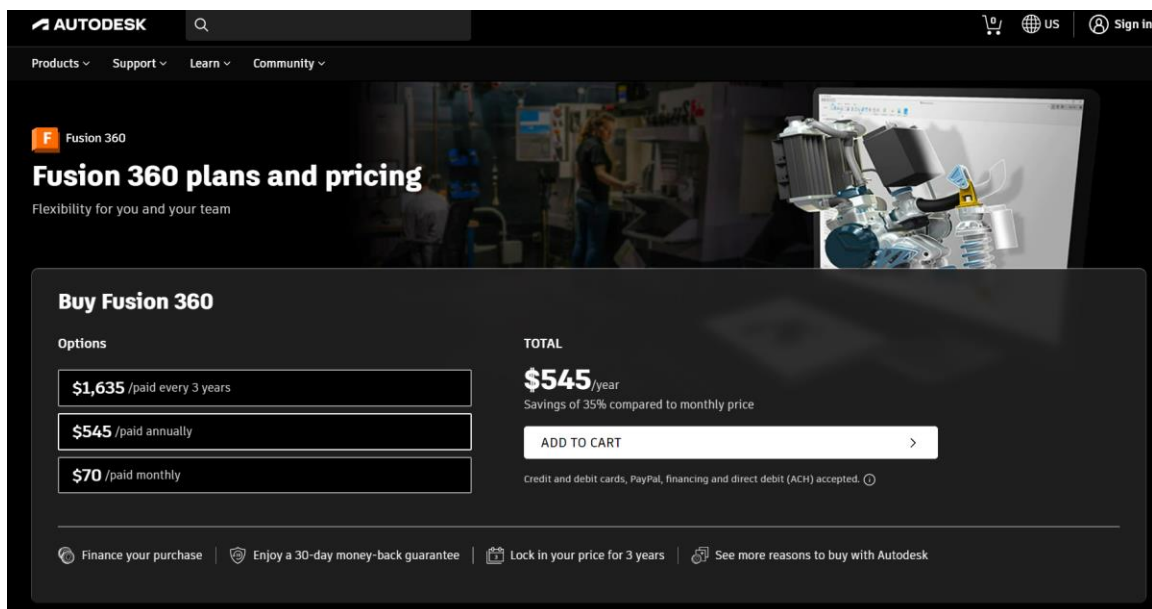


Figure 41 - Fusion 360 Costing

Top Ansys Discovery Alternatives

 Ansys Discovery	 Solid Edge ↗	 SimScale ↗	 Simcad Pro
VISIT WEBSITE ↗	VISIT WEBSITE ↗	VIEW PROFILE	
Overall Rating: ★★★★☆ 3.9 (15)	Overall Rating: ★★★★☆ 4.3 (40)	Overall Rating: ★★★★☆ 4.5 (106)	Overall Rating: ★★★★☆ 4.9 (14)
Ease of Use ★ 3.8	Ease of Use ★ 4.0	Ease of Use ★ 4.2	Ease of Use ★ 4.4
Customer Service ★ 4.5	Customer Service ★ 3.9	Customer Service ★ 4.6	Customer Service ★ 4.9
Features ★ 3.5	Features ★ 4.2	Features ★ 4.1	Features ★ 4.8
Value for Money ★ 3.8	Value for Money ★ 4.1	Value for Money ★ 4.5	Value for Money ★ 4.9
Starting from: Not provided by vendor	Starting from: \$75.00 /Per-Month	Starting from: Not provided by vendor	Starting from: \$4950.00 /One-Time
Pricing Model: Per Feature	Pricing Model: Per Feature		Pricing Model: Flat Rate
Core Features 1/14	Core Features 9/14	Core Features 6/14	Core Features 13/14

Figure 42 - Ansys Discovery Compared to Competitors

Home / PTC / PTC Creo Simulation Live - 1 Year Subscription

PTC Creo Simulation Live - 1 Year Subscription

SKU: 18606 MPN: SPN-3392-F UPC:

Subscription

**PTC**

Options

☒ PTC Creo Simulation Live - Floating License - 1 Year Subscription

☐ PTC Creo Simulation Live - 1 Year Subscription

Ground-breaking technology to perform structural, thermal, and modal analysis on 3D CAD designs in seconds.

No more back and forth; no separate environments. Created especially for design engineers, the analysis updates dynamically in real-time as you edit, create new features, or change properties.

**ptc** AUTHORIZED RESELLER

\$8,110

As low as \$249.75/month with CREDIT KEY

1

[Add to Cart](#)

[Ask for Quote](#)

TALK TO OUR EXPERTS 866.362.8977

Digital Delivery As in

Got any questions? I'm happy to help.

Figure 43 - Creo Simulation Cost

44

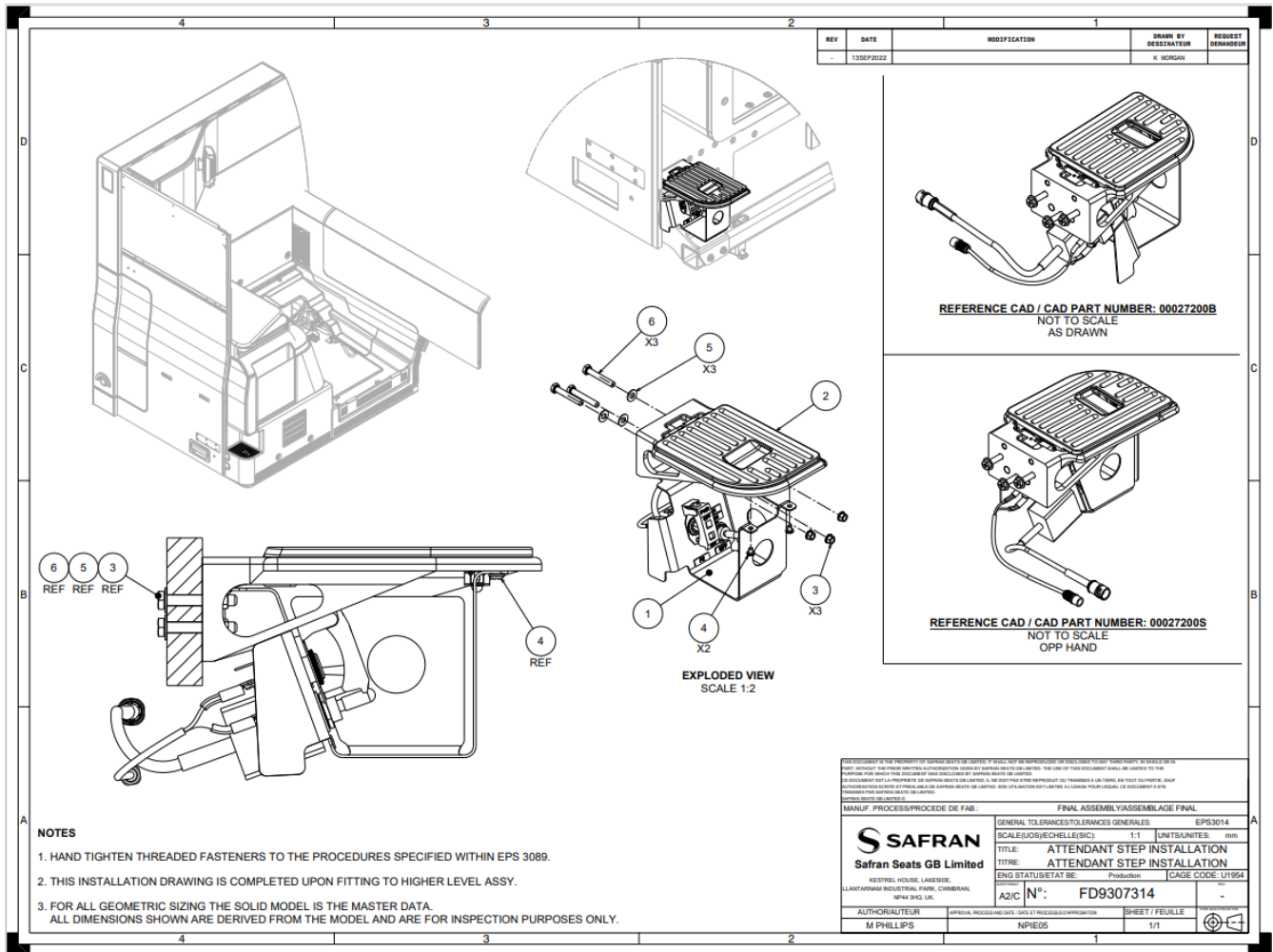


Figure 44 - Crew Step Installation Drawing

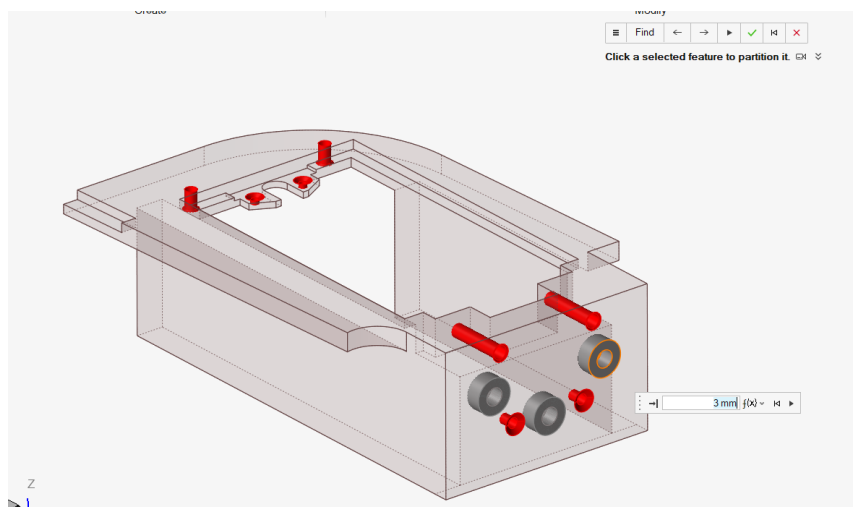


Figure 45 - Defining Partitions

Recommended Applications					Production process Procédé de fabrication	Form Forme	Material (standard) Matériau (Norme)	Type	Caractéristiques mécaniques	
Primary structure Structure primaire		Secondary structure Structure secondaire		Leaf or Wire spring Lame ou Fil ressort					Mechanical characteristics ¹⁶ Rm [MPa] Re [MPa]	Density Densité (g/cm3)
Standard	Requiring a High Capacity for deformation and Energy Absorption	Standard	Weight saving Gain en masse ⁵							
					Plaque / Plate	7075 T651 (EN 485-2, AMS-QQ-A-250/12) T6 EN 485-2	AL Alloy	Rm > 540 Re > 460	2.8	
						15CrMoV6 +QT11 (NF EN 3525)	Low Alloy Steel	Rm = 1080-1280 Re > 930 A% > 10%	7.8	
						AISI 4130 +QT per AMS 6350 25CrMo4 +QT per ISO683-2	Low Alloy Steel	Rm > 862	7.8	
						XSCrNiCuNb16-4+1 +P1070 (EN 10088-2) 17-4 PH H1025 ASTM A693	CRES	Rm = 1070 à 1270 Re > 1000 A% > 10%	7.8	
						2024-T351 (EN 485-2, AMS 4037, AMS-QQ-A-250/4) T3 EN 485-2	AL Alloy	Rm > 400 Re > 290	2.8	

Figure 46 - Required Material List (RML) used within Safran

Parts and Materials							
Parts	Material Library	My Materials					
Material	E	Nu	Density	Yield Stress	α	λ	
Steel (AISI 304)	195.000E+03 MPa	0.290	8.000E-3 g/mm3	215.000E+00 MPa	17.300E-06 /K	16.200E-03 W/(mm ² K)	
Steel (AISI 316)	195.000E+03 MPa	0.290	8.000E-3 g/mm3	205.000E+00 MPa	16.000E-06 /K	16.300E-03 W/(mm ² K)	
Steel (AISI 1015)	200.000E+03 MPa	0.290	7.870E-3 g/mm3	285.000E+00 MPa	11.900E-06 /K	51.900E-03 W/(mm ² K)	
Steel (AISI 1040)	200.000E+03 MPa	0.290	7.850E-3 g/mm3	350.000E+00 MPa	11.300E-06 /K	50.700E-03 W/(mm ² K)	
Steel (AISI 1080)	200.000E+03 MPa	0.290	7.870E-3 g/mm3	380.000E+00 MPa	14.700E-06 /K	48.100E-03 W/(mm ² K)	
Steel (AISI 4130)	200.000E+03 MPa	0.290	7.870E-3 g/mm3	360.000E+00 MPa	13.700E-06 /K	42.700E-03 W/(mm ² K)	
Steel (AISI 4142)	200.000E+03 MPa	0.290	7.870E-3 g/mm3	585.000E+00 MPa	12.200E-06 /K	42.600E-03 W/(mm ² K)	
Aluminum (2024-T3)	75.000E+03 MPa	0.330	2.770E-3 g/mm3	275.800E+00 MPa	22.800E-06 /K	121.000E-03 W/(mm ² K)	
Aluminum (2024-T6/T8)	75.000E+03 MPa	0.330	2.770E-3 g/mm3	275.800E+00 MPa	22.800E-06 /K	151.000E-03 W/(mm ² K)	
Aluminum (6061-T6)	75.000E+03 MPa	0.330	2.700E-3 g/mm3	241.300E+00 MPa	23.500E-06 /K	167.000E-03 W/(mm ² K)	
Aluminum (7075-T6)	75.000E+03 MPa	0.330	2.800E-3 g/mm3	413.700E+00 MPa	23.200E-06 /K	130.000E-03 W/(mm ² K)	

Figure 47 - Inspire 2024-T3 Material Properties

2024-T351 (EN 485-2, AMS 4037, AMS-QQ-A-250/4) T3 EN 485-2	AL Alloy	Rm > 400 Re > 290	2,8	e = 6,5 à 100 mm 0,25" to 3,94"
--	----------	----------------------	-----	------------------------------------

Figure 48 - SSGB 2024-T351 Material Properties

Typical overall Factors of Safety

Typical overall *Factors of Safety*:

Equipment	Factor of Safety - FOS -
Aircraft components	1.5 - 2.5
Bollers	3.5 - 6
Bolts	8.5
Cast-iron wheels	20
Engine components	6 - 8
Heavy duty shafting	10 - 12
Lifting equipment - hooks ...	8 - 9
Pressure vessels	3.5 - 6
Turbine components - static	6 - 8
Turbine components - rotating	2 - 3
Spring, large heavy-duty	4.5
Structural steel work in buildings	4 - 6
Structural steel work in bridges	5 - 7
Wire ropes	8 - 9

Table 12 - Factor of Safety (The Engineering Toolbox, 2023)

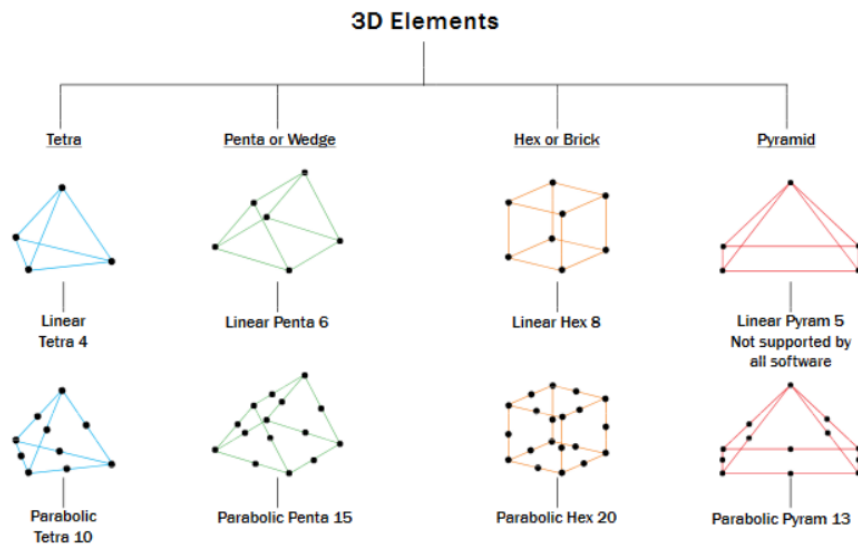


Figure 49 - 3D Elements

Run	Mass Total	Mass 00014636B	Compliance	Contacts	Load Cases	Objective	Speed/Accuracy	Stress	Thickness (Min)	Type	
00014636B -Final Optimisation Min Mass SF 1.5 (4)	1.236e+02 g	6.650e+01 g	8.339e-01	96.10%	Only Sliding	Load Case 1	Min Mass	Faster	1.5	0.000e+00 mm	Topology
00014636B -Final Optimisation Min Mass SF 1.5 (5)	1.334e+02 g	7.627e+01 g	8.678e-01	100.00%	Only Sliding	Load Case 1	Min Mass	More Accurate	1.5	0.000e+00 mm	Topology

Table 13 - Comparison between Faster Vs Accurate

00014636B -Fina_	00014636B -Fina_	✓	03/12/2023 15:49:16	100.19 MB	00:26:13
00014636B -Fina_	00014636B -Fina_	✓	03/12/2023 15:19:57	57.70 MB	00:04:46

Table 14 - Time Comparison Faster Vs Accurate



Figure 50 - A350-1000 LOPA

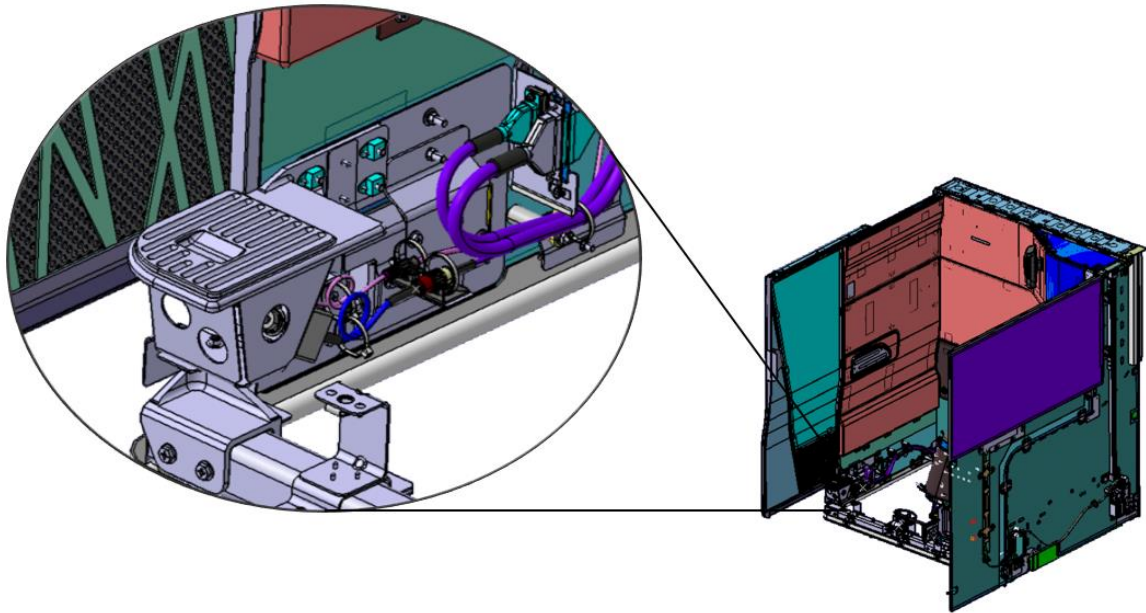


Figure 51 - 000014059B Attachment to Composite Shroud

aPriori

Part Cost Report

Part Number 00014636B - PRE_OPTIMISATION

Scenario Initial

Description Jal BC

Revision -

Process Group Stock Machining

Digital Factory Safran-China Southwest Sichuan Chengdu

Material Aluminum, Stock, ANSI 2024

Batch Size48

Annual Volume48

Production Life1

Total Planned Volume48

Cost Target (USD)-

Amount Variance (USD)-

Percent Variance0%

Total Projected Cost Difference (USD)-

Fully Burdened Cost (USD)66.68

Rough Mass (kg)2.38

Finish Mass (kg)0.21

Material Utilization9%

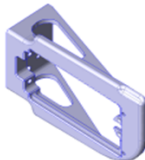
Material Unit Cost (USD / kg)8.42

Date costed Mar 13, 2023

Costed by Sean Colegate

Currency USD

Unit System Metric

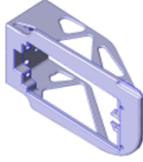


		Processes				
		1	2	3	4	5
	Part Totals	Material Stock	Band Saw	4 Axis Mill	Sand Blast	Chromate Conversion
Manufacturing Times						
Labor Time (s)	4,193.65	0.00	138.87	4,054.78	0.00	0.00
Cycle Time (s)	4,161.60	0.00	106.82	4,054.78	0.00	0.00
Batch Setup Time (hr)	8.24	0.00	0.17	7.07	0.00	1.00
Manufacturing Rates (USD / hr)						

Figure 52 - Apriori Cost Report Pre Optimisation - Case Study 1

Part Cost Report

Part Number	00014636B - OPTIMISATION_PART_FINAL_1	Rough Mass (kg)	2.38	Date costed	Mar 13, 2023
Scenario	Initial	Finish Mass (kg)	0.15	Costed by	Sean Colegate
Description	-	Material Utilization	6%	Currency	USD
Revision	-	Material Unit Cost (USD / kg)	8.42	Unit System	Metric
Process Group	Stock Machining				
Digital Factory	Safran-China Southwest Sichuan Chengdu				
Material	Aluminum, Stock, ANSI 2024				
Batch Size	48				
Annual Volume	48				
Production Life	1				
Total Planned Volume	48				
Cost Target (USD)	-				
Amount Variance (USD)	-				
Percent Variance	0%				
Total Projected Cost Difference (USD)	-				
Fully Burdened Cost (USD)	82.05				

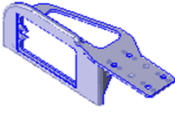


		1	2	3	4	5
	Part Totals	Material Stock	Band Saw	4 Axis Mill	Sand Blast	Chromate Conversion
Manufacturing Times						
Labor Time (s)	4,179.48	0.00	140.75	4,038.72	0.00	0.00
Cycle Time (s)	4,147.00	0.00	108.27	4,038.72	0.00	0.00
Batch Setup Time (hr)	14.57	0.00	0.17	13.40	0.00	1.00
Manufacturing Rates (USD / hr)						

Figure 53 - Apriori Cost Report Post Optimisation - Case Study 1

Part Cost Report

Part Number	00014059B_PRE_OPTIMISED_CASE_STUDY_2	Rough Mass (kg)	5.58	Date costed	24-Apr-2023
Scenario	Initial	Finish Mass (kg)	0.24	Costed by	Sean Colegate
Description	Jal Bc	Material Utilization	4%	Currency	USD
Revision	-	Material Unit Cost (USD / kg)	8.42	Unit System	Metric
Process Group	Stock Machining				
Digital Factory	aPriori China-Southwest-Sichuan-Chengdu				
Material	Aluminum, Stock, ANSI 2024				
Batch Size	30				
Annual Volume	30				
Production Life	1				
Total Planned Volume	30				
Cost Target (USD)	-				
Amount Variance (USD)	-				
Percent Variance	0%				
Total Projected Cost Difference (USD)	-				
Fully Burdened Cost (USD)	81.46				

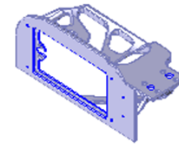


		1	2	3
	Part Totals	Material Stock	Band Saw	4 Axis Mill
Manufacturing Times				
Labor Time (s)	1,439.38	0.00	99.30	1,340.08
Cycle Time (s)	1,416.47	0.00	76.39	1,340.08
Batch Setup Time (hr)	4.55	0.00	0.17	4.38
Manufacturing Rates (USD / hr)				

Figure 54 - Apriori Cost Report Pre Optimisation - Case Study 2

Part Cost Report

Part Number 00014059B_OPTIMISED_CASE_STUDY_2	Rough Mass (kg)	4.68	Date costed 24-Apr-2023
Scenario Initial	Finish Mass (kg)	0.20	Costed by Sean Colegate
Description Jal BC	Material Utilization	4%	Currency USD
Revision -	Material Unit Cost (USD / kg)	8.42	Unit System Metric
Process Group Stock Machining			
Digital Factory aPriori China-Southwest-Sichuan-Chengdu			
Material Aluminum, Stock, ANSI 2024			
Batch Size 30			
Annual Volume 30			
Production Life 1			
Total Planned Volume 30			
Cost Target (USD) -			
Amount Variance (USD) -			
Percent Variance 0%			
Total Projected Cost Difference (USD) -			
Fully Burdened Cost (USD) 104.15			



Processes				
		1	2	3
	Part Totals	Material Stock	Band Saw	4 Axis Mill
Manufacturing Times				
Labor Time (s)	2,470.16	0.00	102.90	2,367.26
Cycle Time (s)	2,446.41	0.00	79.15	2,367.26
Batch Setup Time (hr)	10.72	0.00	0.17	10.55
Manufacturing Rates (USD / hr)				

Figure 55 - Apriori Cost Report Post Optimisation - Case Study 2

Bibliography

Abu-Taieh, E., 2019. *Simulation Modelling Practice and Theory*. London: IntechOpen.

Aerospace Technology Institution, 2023. *ATI FIXED TRADE CALCULATOR*. [Online]

Available at: <https://portal.ati.org.uk/fixed-trade-calc>

[Accessed 29 April 2023].

Alexander, C., 1964. *Notes on the Synthesis of Form*, New York: McGraw Hill.

Altair, 2018. *Link between the analyse and the optimization*. [Online]

Available at:

https://community.altair.com/community?id=community_question&sys_id=f4668cf61b2bd0908017dc61ec4bcb82

[Accessed 12 March 2023].

Altair, 2023. *Inspire*. [Online]

Available at: <https://altair.com/inspire>

[Accessed 20 March 2023].

Ansys, 2023. *Ansys Discovery*. [Online]

Available at: <https://www.ansys.com/products/3d-design/ansys-discovery#tab1-2>

[Accessed 5 March 2023].

Autodesk, 2022. *Transition To Named User*. [Online]

Available at: <https://www.autodesk.com/campaigns/transition-to-named-user>

[Accessed 23 February 2023].

Autodesk, 2023. *Fusion360*. [Online]

Available at: <https://www.autodesk.com/products/fusion-360/overview?term=1-YEAR&tab=subscription>

[Accessed 5 March 2023].

Bendsoe, M. P., 1989. Optimal shape design as a material distribution. *Struct Optim*, Volume 1, pp. 193-202.

Bendsoe, M. P., 2003. *Topology Optimization*. s.l.:Springer Science & Business Media.

Bethany, 2017. *How CAD Has Evolved Since 1982*. [Online]

Available at: <https://www.scan2cad.com/blog/cad/cad-evolved-since-1982/>

[Accessed 24 February 2023].

Bonsignore, C., 2019. Chapter 14 - Device Design and Computational Simulation. In: C. P. Cheng, ed. *Handbook of Vascular Motion*. s.l.:Academic Press, pp. 291-312.

Bouwer, J., 2022. Taking stock of the pandemic's impact on global aviation. *Mckinsey & Company*.

Bray, S., 2022. *Carbon Taxes in Europe*, Washington: Tax Foundation.

Brethower, D. D., 2010. *Behavioral Systems Analysis*, s.l.: Cambridge Center for Behavioral Studies.

Britannica, 2021. *Encyclopedia Britannica*. [Online]

Available at: <https://www.britannica.com/technology/computer-simulation>

[Accessed 2023 January 2023].

Burg, D., 2021. *Moore's Law revisited through Intel chip density*. [Online]

Available at: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0256245>

[Accessed 25 April 2023].

Creo®, 2023. *Creo Simulate*. [Online]

Available at: https://www.ptc.com/-/media/Files/PDFs/CAD/Creo/Creo_Simulate_Datasheet-English.PDF

[Accessed 6 March 2023].

Cunningham, B., 2015. *Simulation-Led Design Is Better and More Accessible than Ever*. [Online]

Available at: <https://www.comsol.com/blogs/simulation-led-design-is-better-and-more-accessible-than-ever/>

[Accessed 18th November 2022].

Dassault Systemes, 2023. *Simulation For Designers*. [Online]

Available at:

https://www.3ds.com/fileadmin/PRODUCTS/SIMULIA/PDF/datasheets/Simulation_for_Designers-Flyer.pdf

[Accessed 10 March 2023].

DeAmicis, C., 2019. *The Decade of Design": How the last 10 years transformed design's role in*. [Online]

Available at: <https://www.figma.com/fr/blog/the-rise-of-ux-ui-design-a-decade-in-reflection/>

[Accessed 21 February 2023].

Dechand, S., 2016. *Rule Of Ten: How To Cut Your Development Costs*. [Online]

Available at: <https://www.code-intelligence.com/blog/rule-of-ten#:~:text=The%20Rule%20of%20Ten%20states,the%20costs%20of%20eliminating%20it.>

[Accessed 24 February 2023].

Djadoudi, H., 2023. *Abaqus Expert Review, Pricing and Alternatives - 2023*, s.l.: Worquick.

Dow, R., 2010. *JPR Report: CAD Industry in Slow Recovery*. [Online]

Available at: <https://www.jonpeddie.com/news/jpr-report-cad-industry-in-slow-recovery/>

[Accessed 24 February 2023].

DOW, R., 2010. *JPR Report: CAD Industry in Slow Recovery*. [Online]

Available at: <https://www.jonpeddie.com/news/jpr-report-cad-industry-in-slow-recovery/>

[Accessed 24 February 2023].

Dow, R., 2011. *JPR releases the 2012 CAD Report*. [Online]

Available at: <https://www.jonpeddie.com/news/jpr-releases-the-2012-cad-report/>

[Accessed 24 February 2023].

Dynatech, 2014. Reducing the weight of aircraft interiors. *Reinforced Plastics*, 58(4), pp. 36-37.

Findeli, A., 2001. Rethinking Design Education for the 21st Century. *Theoretical , Methodological , and Ethical Discussion*, 17(1), pp. 5-17.

Huang, R., 2016. Energy and Emissions Sacing Potential of Additive Manufacturing: The caseof Lightweight Aircraft Components. *Journal of Cleaner Production*, Volume 135, pp. 1559-1570.

HUBS, 2023. *14 proven design tips to reduce the cost of CNC machining*. [Online]
Available at: <https://www.hubs.com/knowledge-base/reducing-cnc-machining-costs-design-tips/>
[Accessed 27 April 2023].

iDataLabs, 2023. *iDataLabs*. [Online]
Available at: <https://enlyft.com/tech/computer-aided-design-engineering>
[Accessed 21 February 2023].

Inspire, 2023. *Loads and Supports*. [Online]
Available at:
https://2021.help.altair.com/2021.1/inspire/en_us/topics/inspire/structure/loads_inspire_c.htm
[Accessed 27 April 2023].

Jet-A1-Fuel, 2023. *Jet Fuel Price*. [Online]
Available at: <https://jet-a1-fuel.com>
[Accessed 24 April 2023].

Johnson, N. S., 2010. *SolidWorks World 2010: Clouds, Macs, Movie Making, and More*. [Online]
Available at: <https://www.cadalyst.com/sww2010>
[Accessed 24 Feb 2023].

Kochhar, N. K., 2003. The role of CAE in product development at Ford Motor Company. In: K. Bathe, ed. *Computational Fluid and Solid Mechanics*. Cambridge: Elsevier Science.

Lawson, B., 1997. *How Designers Think*. 3rd ed. Gillingham: Scribe Design.

Lawson, B., 2006. *How designers think: The design process demystified*. Routledge.

Lee, H. B. C., 1994. Designing products and processes for postponement. *Management of Design*, pp. 105-122.

Liu, Y., 2013. *Effects of Mesh Density on Finite Element Analysis*, Louisiana: SAE International.

Mahdavi, A., 2004. Topology optimization of 2D continua for minimum compliance. *Structural and Multidisciplinary Optimization*, 32(2), pp. 121-132.

Maher, K., 2012. *A MIDTERM TEST FOR THE CAD INDUSTRY*. [Online]
Available at: <https://gfxspeak.com/archives/a-midterm-test-for-the-cad-industry/>
[Accessed 24 February 2023].

Markets, M. a., 2022. *Aircraft Seating Market*, s.l.: s.n.

Martin, H., 2018. *United Airlines saves 643,000 litres of fuel by using lighter paper on inflight magazine*. [Online]
Available at: <https://www.traveller.com.au/united-airlines-saves-643-litres-of-fuel-by-using-lighter-paper-on-inflight-magazine-h0nfej#ixzz5c6aJITkq>
[Accessed 12 March 2023].

Martins, J. A., 2022. The Importance of Accurate Boundary Condition in Obtaining Reliable Shearing Stresses on a Torsional Finite Element Solution. In: *Engineering, Technology & Applied Science Research*. São Paulo: s.n., pp. 8482-8487.

Mordor Intelligence, 2021. *GLOBAL COMMERCIAL AIRCRAFT CABIN SEATING MARKET - SIZE, SHARE, COVID-19 IMPACT & FORECASTS UP TO 2029*. [Online]
 Available at: <https://www.mordorintelligence.com/industry-reports/aircraft-seating-market>
 [Accessed 24 April 2023].

Nagy, D., 2017. *Design optimization*. [Online]
 Available at: <https://medium.com/generative-design/design-optimization-2ec2ba3b40f7#:~:text=The%20optimization%20problem%20is%20defined,the%20feasibility%20of%20any%20design.>
 [Accessed 12 March 2023].

Nguyen, J., 2022. *Why do computers get more powerful, but cost the same?*. [Online]
 Available at: <https://www.marketplace.org/2022/09/16/why-do-computers-get-more-powerful-but-cost-the-same/>
 [Accessed 24 February 2023].

Obayashi, Y., 2022. *Japan's carbon pricing scheme being launched in April*. [Online]
 Available at: <https://www.reuters.com/markets/carbon/japans-carbon-pricing-scheme-being-launched-april-2023-03-30/#:~:text=The%20carbon%20levy%20will%20be,low%20but%20will%20gradually%20rise.>
 [Accessed 2 May 2023].

Orme, M., 2018. Topology Optimization for Additive Manufacturing. *Design and Applications of Additive Manufacturing and 3D Printing*, Volume 2.

Pfeifer, M., 2009. Chapter 6 - Degradation and Reliability of Materials. In: Elsevier, ed. *Chapter 6 - Degradation and Reliability of Materials*. s.l.:Butterworth-Heinemann, pp. 161-187.

Roser, M., 2022. *Technological Change*. [Online]
 Available at: <https://ourworldindata.org/technological-change>
 [Accessed 2023 February 2023].

Rosinha, I. P., 2015. Topology optimization for biocatalytic microreactor configurations. *Computer Aided Chemical Engineering*, Volume 37, pp. 1463-1468.

Sajid, M., 2019. Simulation Based Measuring the Benefits of Converting to Lean Product Design and Development: A Case Study of Manufacturing Sector in Pakistan. *Advances in Science and Technology*, 13(1), pp. 128-137.

Saran, C., 2019. *Stanford University finds that AI is outpacing Moore's Law*, s.l.: Tech Target.

Scan2CAD, 2021. *CATIA vs Fusion 360: CAD Software Compared*. [Online]
 Available at: <https://www.scan2cad.com/blog/cad/catia-vs-fusion-360/>
 [Accessed 5 March 2023].

Siemens, 2023. *Simcenter STAR-CCM+*. [Online]
 Available at: <https://www.plm.automation.siemens.com/global/en/products/simcenter/STAR->

CCM.html

[Accessed 20 March 2023].

SimScale, 2022. *Initial Conditions*. [Online]

Available at: <https://www.simscale.com/docs/simulation-setup/initial-conditions/>

[Accessed 5 March 2023].

SimScale, 2023. *STRUCTURAL AND THERMAL*. [Online]

Available at: <https://explore.simscale.com/hubfs/resources/datasheet/datasheet-simscale-structural-and-thermal.pdf>

[Accessed 6 March 2023].

Stalk, G. J., 1993. Japan's dark side of time. *Harvard Business Review*, pp. 93-102.

Technavio, 2021. *Computer-Aided Design Market by End-user and Geography - Forecast and Analysis 2021-2025*, s.l.: s.n.

The Engineering Toolbox, 2023. *The Engineering Toolbox*. [Online]

Available at: https://www.engineeringtoolbox.com/factors-safety-fos-d_1624.html

[Accessed 12 March 2023].

TrustRadius, 2023. *Simulation Software*. [Online]

Available at:

<https://www.trustradius.com/simulation#:~:text=The%20price%20of%20simulation%20software,%24100%20to%20%241%2C000%20per%20month.>

[Accessed 5 March 2023].

Williams-Wood, T., 2020. *Advantages and Disadvantages of Simulation* [Interview] (12 March 2020).

Zhou, B., 2020. *Quantum Error Correction Codes*, Arizona: University of Arizona, Department of Physics.