Designing the interactions for Digital thread

-CS Archana-

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Declaration

I declare that this written submission represents my ideas in my own words, and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources that have thus not been properly cited, or from whom proper permission has not been taken when needed.

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Approval Sheet

This thesis entitled "Designing the interaction for digital thread" by CS Archana is approved for the degree of Master of Technology from IIT Hyderabad.

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Abstract

Aircraft design is a complex design process involving multiple personas. It takes years of testing before any novel technology is introduced. There is a severe urge for intervention to address the prevailing incertitude, and pace up the whole process. The digital twin, one of the cardinal technologies in Industry 4.0, can be adopted as one of the solutions. This technology has leveraged the design and testing system to the next level through the ability to predict the product's future in the PLM cycle. In the area of the digital twin, a model-based digital twin is one of the most unexplored areas but has the far-reaching potential to predict the future of any product even before its establishment. One segment of this research tries to explore how model-based digital twins can be used to design and test new technology in aircraft. Another segment of this paper tries to explore, how implicit interaction (a type of intelligent interaction) can be used to experience the interaction with a model-based Digital twin. Implicit interaction is a proactive human-AI interaction where the system does not wait for a user input but instead actively initiates and completes a task based on the system's intelligence, which the system acquires through learning from human interactions. This proactive AI system is focused to reduce the cognitive load of the user by automating the user task. In the current scenario, most of the digital twin interactions use explicit interactions. Existing research has not explored the potential of implicit interactions while interacting with model-based Digital twins. This research is mainly proposing to traverse the potential of creating a new experience of implicit interaction for aircraft designers while interacting with the model-based digital twin.

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Introduction

I did my thesis project with siemens R&D. I was offered a five-month internship with Siemens, and I played the role of UX researcher here. The project is guided by Prof Ankita Roy (In academics) and Mr. Ramesh Manickam(in the industry). My area of interest was in the digital thread and digital twin, and the project is titled "CCTM4: Designing for the Human world interface". During these five months, the main intention was to establish a new interaction framework for interacting with digital threads. Currently, Siemens has developed their own XST database for interacting with digital threads, but there are a lot of challenges concerning the interaction with these digital threads. The project began with secondary research, where I broadened my horizons to understand the concept of digital threads. The definition of the digital thread vastly depends on multiple individual business tasks and information from the past from the product lifecycle. The information from the digital thread is essential for constructing the digital twin. The pillars of the existence of digital thread are automation, traceability, and the digital footprint of products. From my desk research, I came up with my framework for interaction, and the same framework was validated with the use case from the aircraft design industry. The Role of the Digital Thread and Digital Twin in Digital Transformation is novel in many areas than the role of the digital twin. The potential when these two areas interweave is still under-explored. The digital thread has a tremendous capability, and just one small piece of this has been explored through this entire project.

Siemens R&D

Siemens R&D advanta focuses on digitalization; they are quite established in the area of a digital twin for multiple services. Recently, the siemens group was the first to create an interactable digital thread, and it took around 20 years of research and development team to develop their prototype. Regarding my contribution to siemens, previously, I had interned with Siemens for two months as part of my summer internship; my project was entitled "Designing experience for interacting with Intelligent systems." During that time, my main focus was on the digital twin and the role of the Digital twin in industries 4.0. I took the use case of the food packaging industry and explored the use of digital twin in a situation when an anomaly takes place in the manufacturing machine. As an extension of my previous summer internship, I continued understanding the core concept of Digital thread application for creating a digital twin.

Chapter 1

Literature survey

1.1 Understanding Digital twin.
1.1.1 History of twin

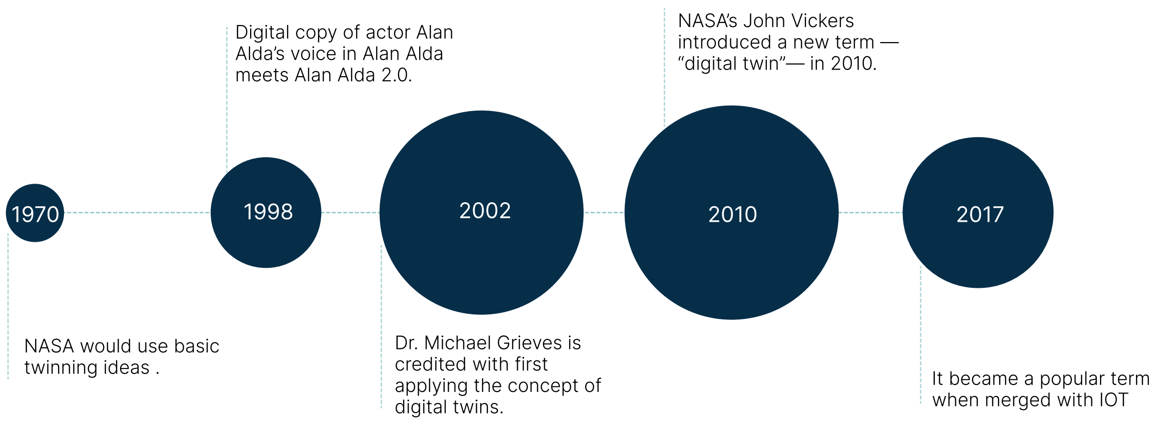


Fig 1.1:History of digital twin

The first digital twin concept was launched in 1960 when NASA used the twining idea during the failure of the Apollo 13 mission. When one of the components failed in space, the base station at NASA found that they could no longer make any right decisions on the original spacecraft because the real module had undertaken massive changes cause of exposure to an extremely adverse situation. Hence they decided to modify the model on the ground which was similar to Apollo 13(Used for training astronauts). This model was modified to closely mirror the existing state of the spacecraft in the space. They used the physical twin to recreate the multiple failure scenarios that took place in the Apollo 13 mission. At this point, they did not use IOT but rather they used high-speed telecommunication technology which was used for two-way communication. Adaptability was one of the key features of this physical-based twin, where they were able to exactly replicate the changes happening in the original Apollo mission.
The next advancement in Digital twin happened in 1998 when a digital copy of Alan Aldas's voice was replicated. In 2002, Micheal Grives first coined the term "Digital twin" which was applied by NASA in 2010. When IOT became popular, the emergence of the digital twin also took place, and it became predominant around 2017[1]

1.1.2 Stages of twin formation

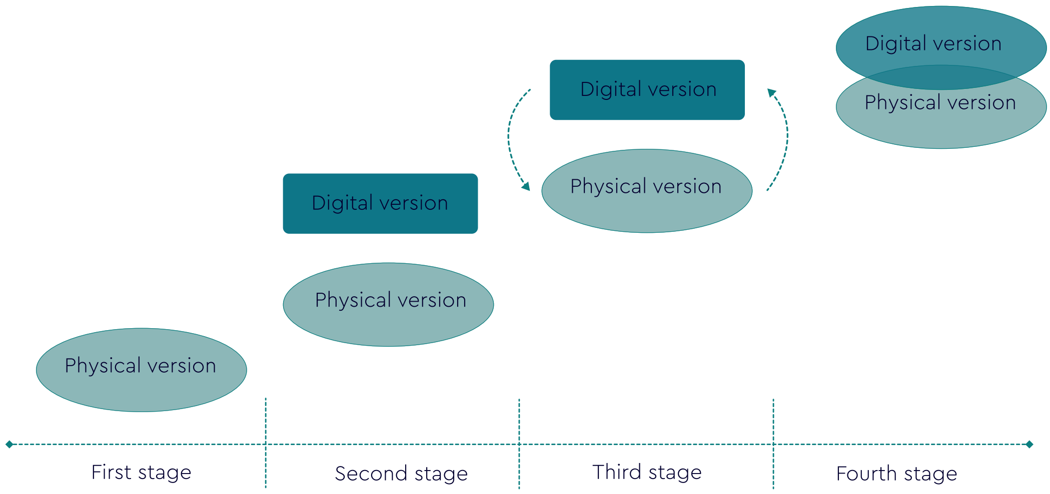


Fig 1.2:Stages of digital twin[2]

Stages:

Physical twin version: Physical simulators(Similar to the apollo 13 mission) are used. Here the actual physical object or a much cheaper replica of the actual product is made as a substitute for a fully functioning product. Also, this could be interactive or could be automatic human in-loop interaction**.**

Digital model: This uses a computerized (CAD)model where the product is replicated visually. The information is not transferred digitally, rather it is done by the designer or engineers. This means that the model is STATIC where the data values are given by a third party.

Digital Model with real-time data transfer: Digital twin concept comes in here. It used a simulation model, but on another hand, it uses real-time data which means twin can change and develop to provide a more active simulation. There is going to be a two-way data flow between the digital and physical products.

Digital version overlapping with physical version: According to Paul Jacobs in the future, there won't be any line between virtual and physical data. It establishes the concept of a metaverse which we are nearing too.[2]

1.1.3 Simulation VS Digital twin

- Simulation- Creation of a model that can be manipulated directedly to see how it would work in the physical world
- It's static
- It is used for predictions

- Digital twin- Creation of a model that can be directedly in the physical world.
- It is Dynamic.
- Real-time information(actual object is built).

1.1.4 Digital twin

A digital twin is a virtual representation synchronized with a physical product, people, or processes, where the virtual data of the real-time data is created.

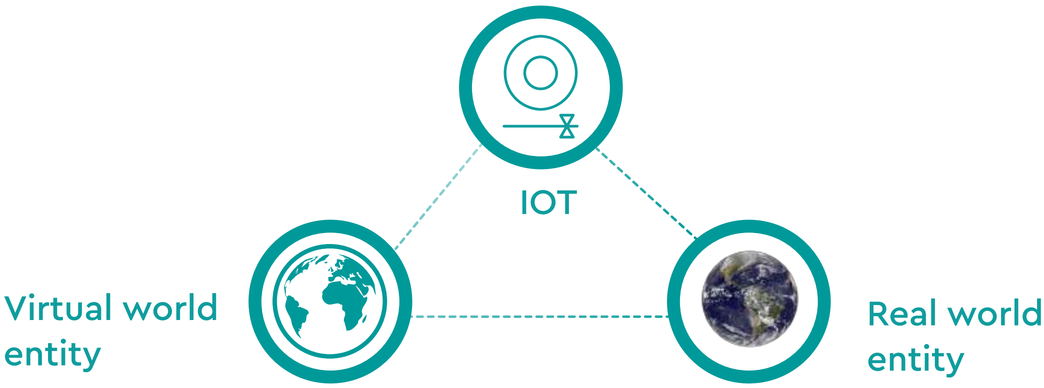


Fig 1.3: Digital twin representation

The diagram above shows how IoT plays a key role in creating the digital twin (Virtual world entity). IoT helps to retrieve the data from the real-time object and send it to a virtual world entity(Simulation).

1.2 Understanding Digital threads

• As described in the paper from MIT-a digital thread is a data-driven architecture that links information/data produced from the product lifecycle to form a large network of interconnected data.
•The concept of digital thread is very simple where the digital information is connected through design, development, manufacturing, testing, release, and inspection of the product.
• A digital thread is a repository of connected information across the product lifecycle which gives an integrated view across domains

1.2.1 Traceability

• Traceability is one of the most important properties of the digital thread, it has all the recorded instances of the product across the entire lifecycle.
All the information right from the design, to the original raw materials from which it was made, the manufacturing processes, and till the inspection is contained by the digital thread.
The purpose of these records is to allow the manufacturer to provide better solutions to their customers to prevent similar failures.
• In the digital thread, it's possible to trace the entire span of the product right from the start to the end of the life span and all of this information is put as one single record in the form of a digital thread.

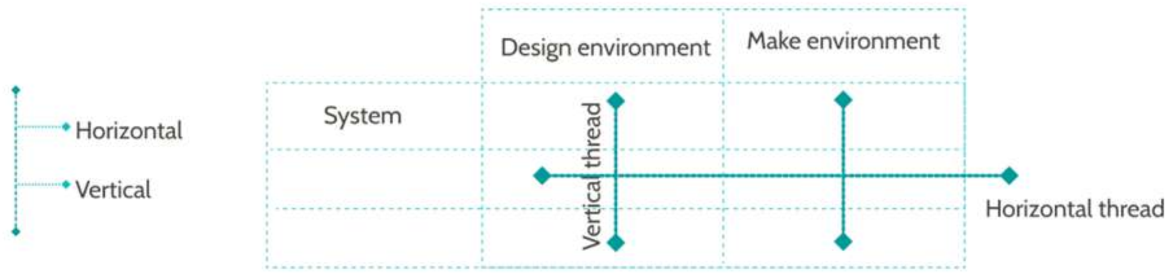
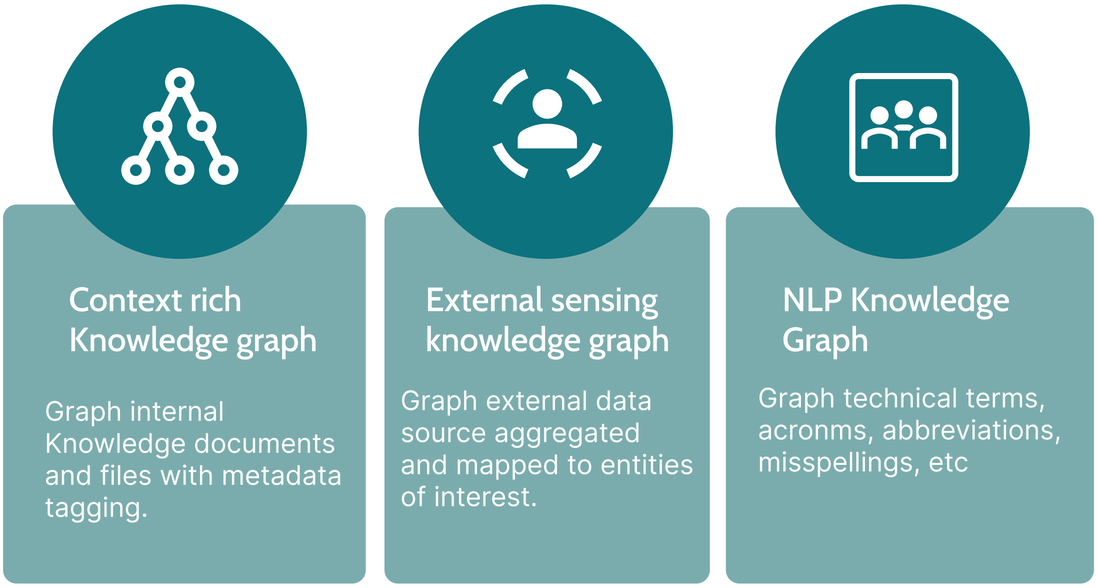


Fig 1.6: Digital thread representation

The digital thread is divided into two parts, vertical and horizontal.
A horizontal thread connects the full lifecycle(Right from the design to inspection) and brings the entire Product lifecycle, and a vertical thread connects the full system down until the final decomposition of most basic elements, for example, all the way to the basic material level.[8]



1.2.2 Relations of KG

In the diagram below, we can see how the digital twin and digital thread are an instance of the knowledge graph.

• Here we can see that the nodes of the digital twin are a subset of the EKG nodes and its edges are a subset of the EKG. Sometimes, different digital twins might have common objects, properties, components, and relations. A digital thread helps to model a digital twin, most of the properties of the digital twin are created by a digital thread.
• Digital thread helps in the traceability of the product while creating a digital twin

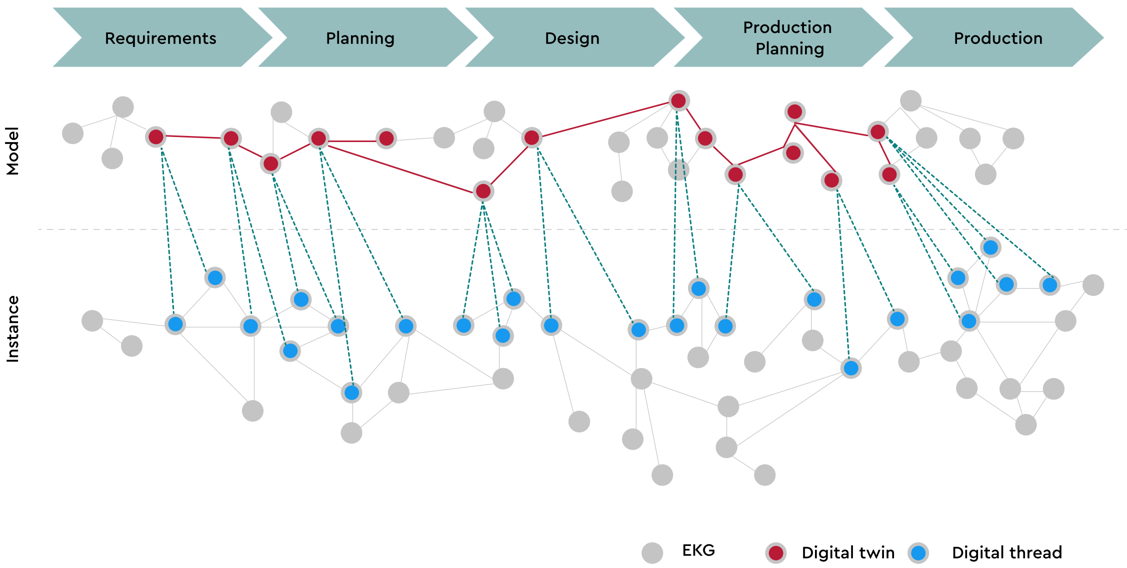


Fig 1.8: Knowledge graph, digital thread and digital twin[10]

1.3 XST Search-Breakup

XST is a unique cross-domain digital thread interaction platform that allows users to directly interact with a digital thread. It's the only digital thread interaction platform. The connections are built on explicit links.

1.3.1 Search

1)User searches for the keywords are searched in the search bar.
2) Static filter bar, where users choose the option to get selective information from the search.

1.3.2 Content

Search output

OPB64718_001_HOUSING_ASM_SHFT_CONT_53596-A

Type:	UGMASTER
Last Modified Date Time:	1289860576000
URL:	http://civ6s465.net.plm.eds.com:3000/#/com.siemens.splm.clientfx.tcui.xrt.showObject?uid=aUCxtwbjxODK0D
Name:	OPB64718_001_HOUSING_ASM_SHFT_CONT_53596-A
Source:	teamcenter

NTSA Report

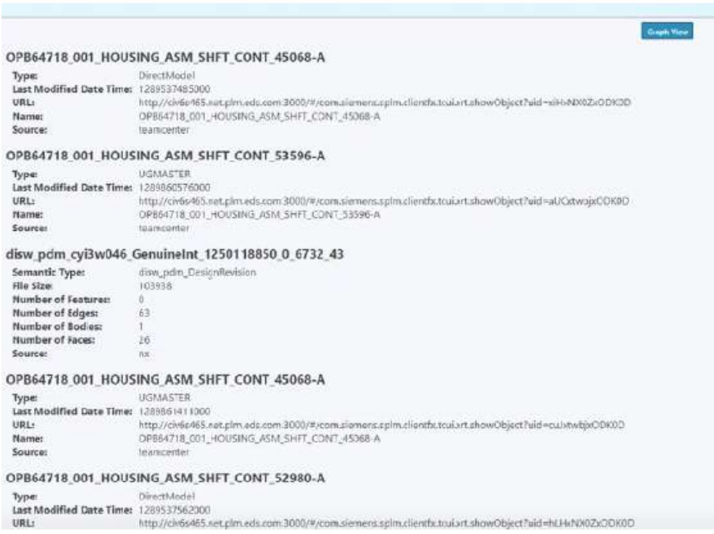
Engine stopped running, looks ignition is off

Crash Date:	1/2/2014
Severity:	Death
Case Number:	912
Mfactor:	Saftey Systems
Crash Location:	Michigan
Source:	nhtsa
Semantic Type:	disw_crash_CrashReport
Related Factor:	Adaptive Equipment
VIN:	4S3BMHB68B3286051
Comment:	Engine stopped running, looks ignition is off
Number of People:	1
ID:	912

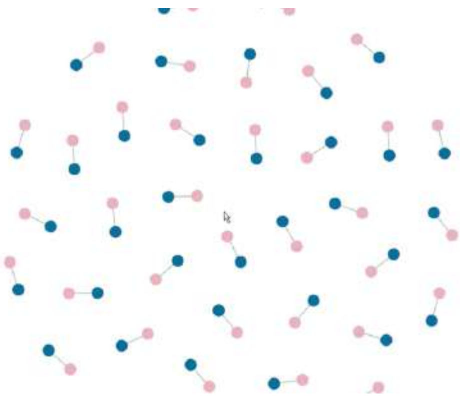
Thread summary

1.3.3 View

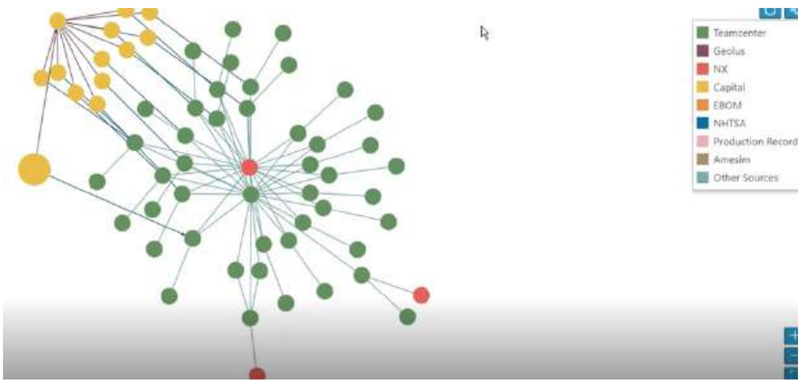
List View



Thread View



1.3.4 Color code



Data source is color coded.
Each node has some information and that information is connected to other nodes.

1.3.5 Current Interactions with Digital thread

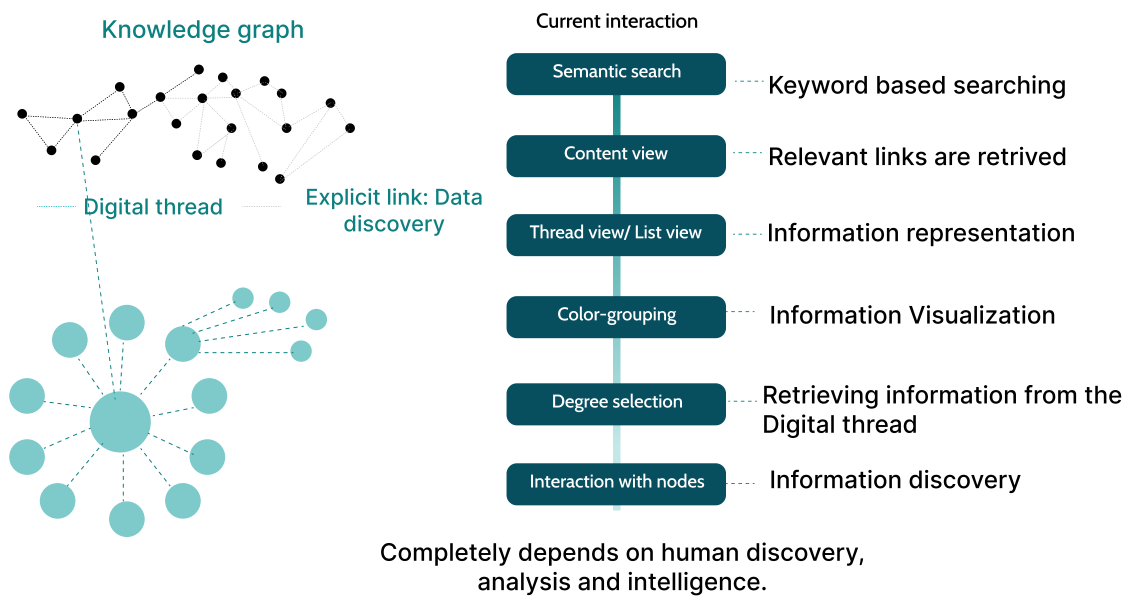


Fig 1.9: Interaction with digital thread

Semantic search: Semantic search is a method in which a search query focuses not only on finding keywords but to determine the context and intent of the word the person is using while searching. The user comes to the system and searches for the keyword.

Content view: The relevant links are retrieved based on the semantic search and this content is made available to the user

Log view/Thread view: The information is presented to the user in the form of a log or thread view. The thread view presents the information in a holistic view of all the data points.

Color grouping: All the information is color grouped according to the type of information.

Degree selection: the nodes made available are according to the degree selected by the user

Interaction with the nodes: The user interacts with the node. The user explores different nodes there links and attachments etc...

1.4 Intelligent interactions

1.4.1 Interactions

Interaction is some kind of direct or interactive communication that takes place between two or more objects which may affect each another.

Stages:
There are four stages of interaction between any two entities.
Intention- Forming a purpose for the interaction. For example, the user should be able to know what different controls do.
Selection- Specifying the action in the interface after forming the intention.
Execution- Executing the action.
Evaluation- Evaluate the system's current state concerning the goal of the user.[11]

1.4.2 Intelligent Interactions

What is Intelligent Interaction?
Interaction where, a machine can learn from the human-machine interaction, and make intelligent predictions during the interactions.

What are Intelligent systems?
An intelligent system is a tool that perceives from the environment, interprets this perception, draws the inference, performs the action and solves the problem, and exhibits intelligent behavior acquired by learning.

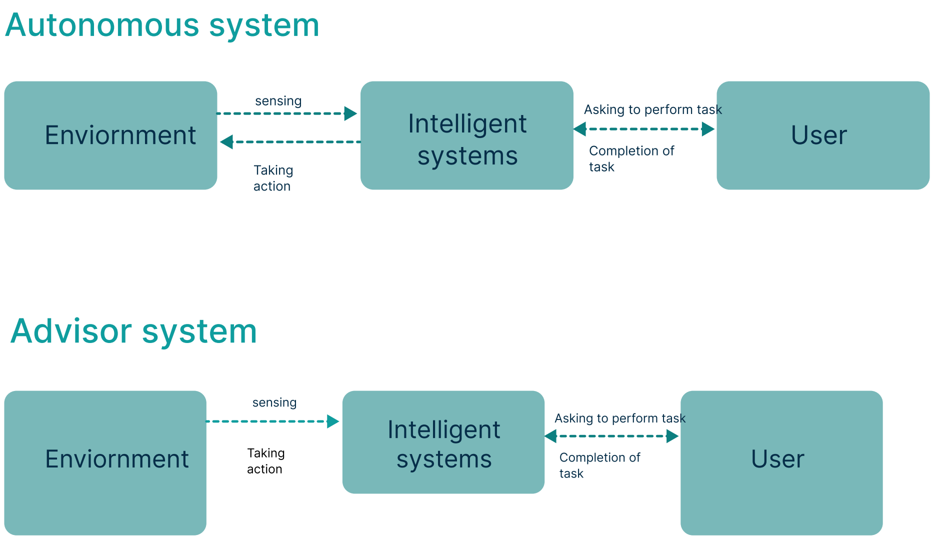


Fig 1.10: Intelligent Interaction

What are the factors guiding intelligence in interaction ?

Behavior: It's the way humans react to any kind of stimuli around them.
Behavior performance: Understanding why humans respond to stimuli in a particular way.
Cognitive modeling: It’s a process in which we try to understand the cognitive process that people go through to complete the task

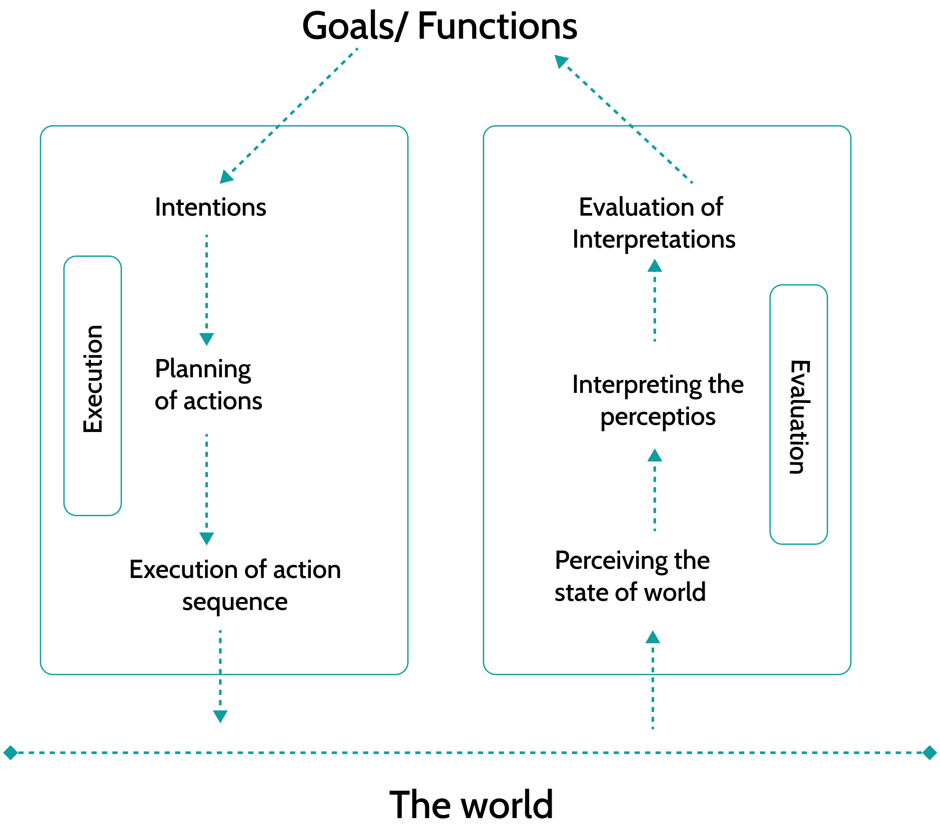


Fig 1.11: Don norman stages of interaction

Intermittent AI Interaction

In the Intermittent human-AI interaction system and users interact with each other in a turn-taking process where the user gives input and then the system gives an output. This is like Alexa.

For this let us take Norman's example of reading a book where the first step is to set a goal or identify a goal that is to read a book. But for the user to read the book he needs more light, which is the next stage.
Hence, a user goes on the execution of the sequence of actions which begins with planning the action, specifying the sequence to be followed, and then performing the same. Also, an experienced user will be capable to carry out these steps subconsciously. After the execution phase comes the evaluation phase, where the user perceives the state of the output and evaluates if the reached goal is his desired goal.[12]

Continuous human-AI interaction

• Continuous human-AI interaction is a system that continuously listens to the stream of user input rather than individual instructions and can respond to this input throughout the interaction.

• These types of systems are very advanced in sensing and processing speed as they have to give continuous outputs to the user input. They are not completely explicit like Alexa but have an implicit property in them.
• Example: Grammarly, where the system highlights the changes that need to be made concerning the spelling or grammar in the text input. These continuously keep improving the text, sometimes it may deviate from the actual goal of the user. It need not be 100 percent right.
• In this type of system, users can ignore the comment of the AI if they want to. [12]

Proactive Human-AI Interaction

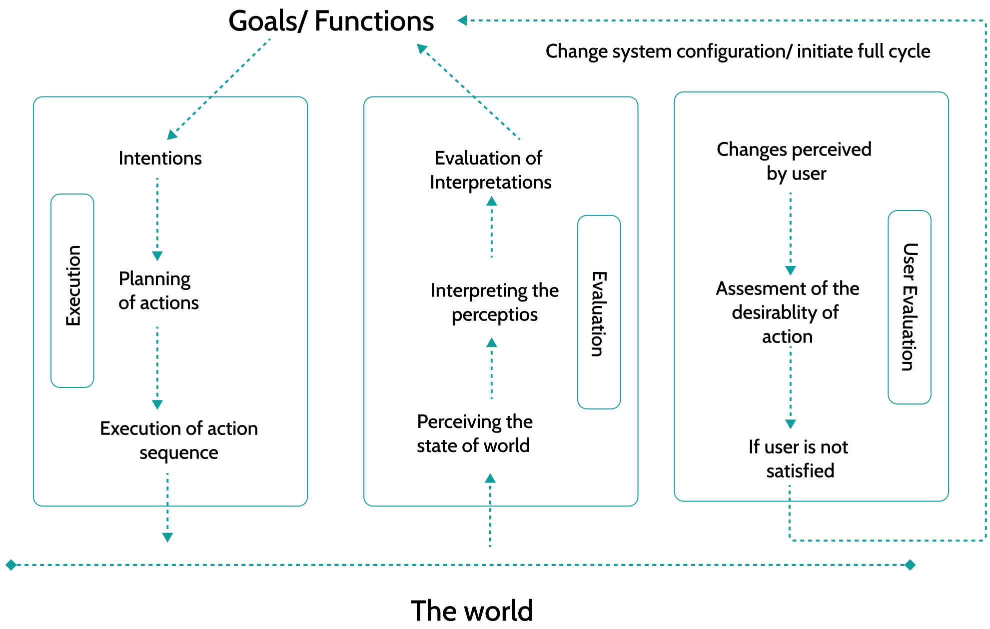


Fig 1.12: Don norman stages of interaction

In the proactive human-AI interaction the system does not wait for a user to give some input rather the system itself actively begins and completes tasks based on the sensor readings. For example, let's consider Norman's example of a user wanting to read a book in surroundings with insufficient lighting, a proper proactive system would set up a home automation system that could increase the brightness of the surrounding automatically after detecting the presence of both user and reduced brightness levels. Hence, the final execution phase, where the user plans and does the action is completely done by the system or can be also called automation. [12]

1.4.3 Interaction attention continuum

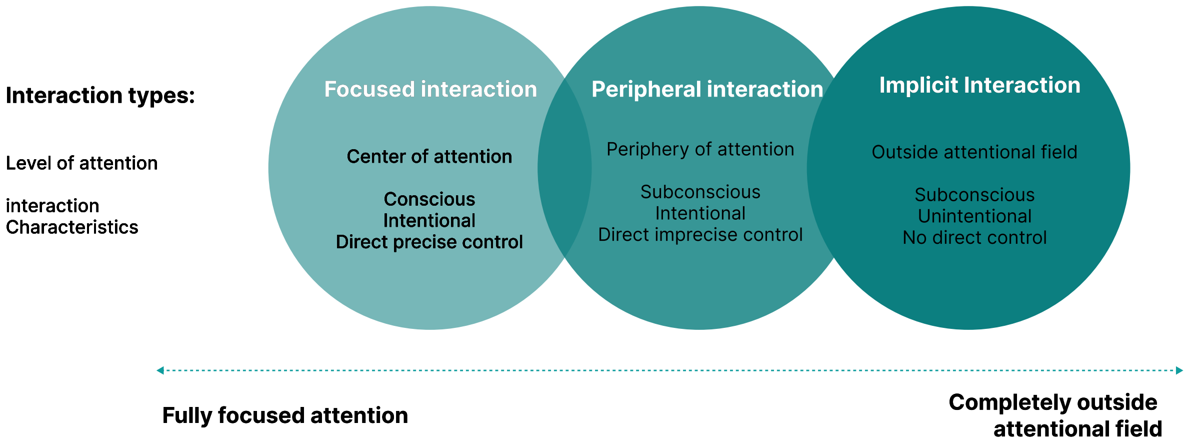


Fig 1.13: Interaction attention continuum

1.5 Implicit interaction

While Designing a new system, the complete attention of the user is not required, and this is called Implicit interaction. This completely occurs outside the attentional field of the users, meaning the system initiates the interaction. The main purpose of this interaction is to reduce the cognitive load of the users, reduce the attention level and understand the context of the user. In the case of focused interaction, the interaction happens with the complete attention of the user where the human analyses the information more than the system. Here all the decisions are intense and are taken after careful deliberations.
The peripheral iteration takes place in the subconscious state of the human mind where the system plays a significant role in the decision-making process. Implicit interaction has two main pillars which are perception and interpretation of the user context.

1.5.1 Degree of implicit interaction

Degree 0- When the user will perform all the tasks by himself.
Degree 1-Where user will perform the task after system alerts
Degree 2- Where the machine will require a very little demand or attention from the user to perform the task

• Degree 3- Where machine will automate, hardly any interaction at all
• It all depends on the amount of control the user is wishing to give the machine.[13]

1.5.2. Implicit interaction framework

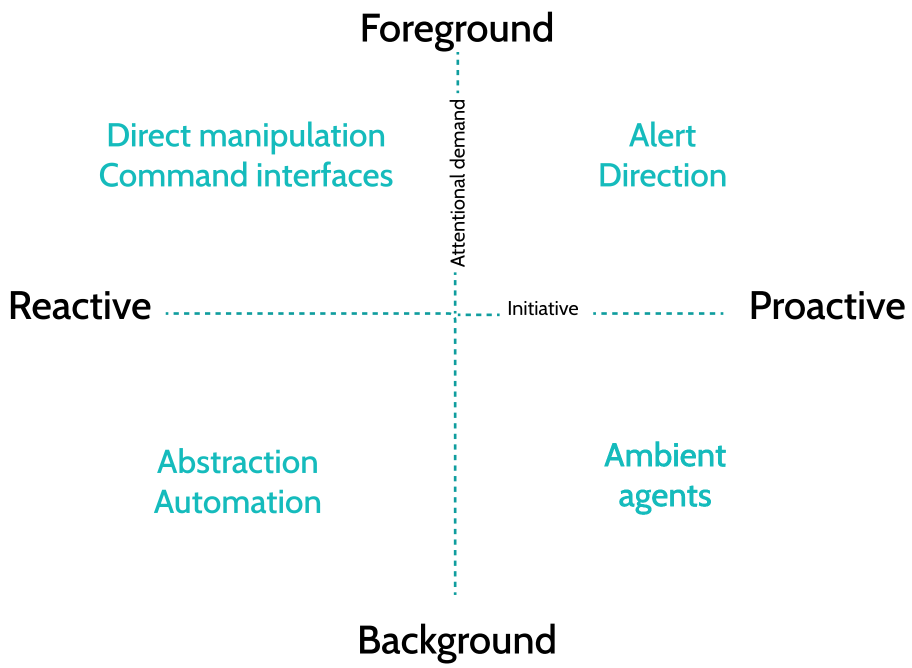


Fig 1.14: Framework for implicit Interaction

Axes of attentional demand and initiative represent the attention needed from the user or the computer system. This mostly describes the level of attention needed from the user or the system.

Few interactions require the attention of users in the foreground and these are called foreground interactions, whereas few interactions exclude the attention of the users and are called background interactions.

Initiative means who initiated the interaction and to what degree are they interacting.

Interactions initiated by the user are reactive interactions, and there are the interactions initiated by the system which are called proactive interactions.

Abstracted - when the partial task is done by humans and in automation, the complete task is done by the system [13]

1.5.3 User-Context Perception Model (UCPM)

The model shown below is the User-Context Perception Model (UCPM) which focuses on how both system and human perceive parallelly and make the decision together in the given system.
While building a context-aware system, it is very important to create a (hierarchical) feature space where a lot of factors need to be created, this features will strongly impact the system behavior. [14]

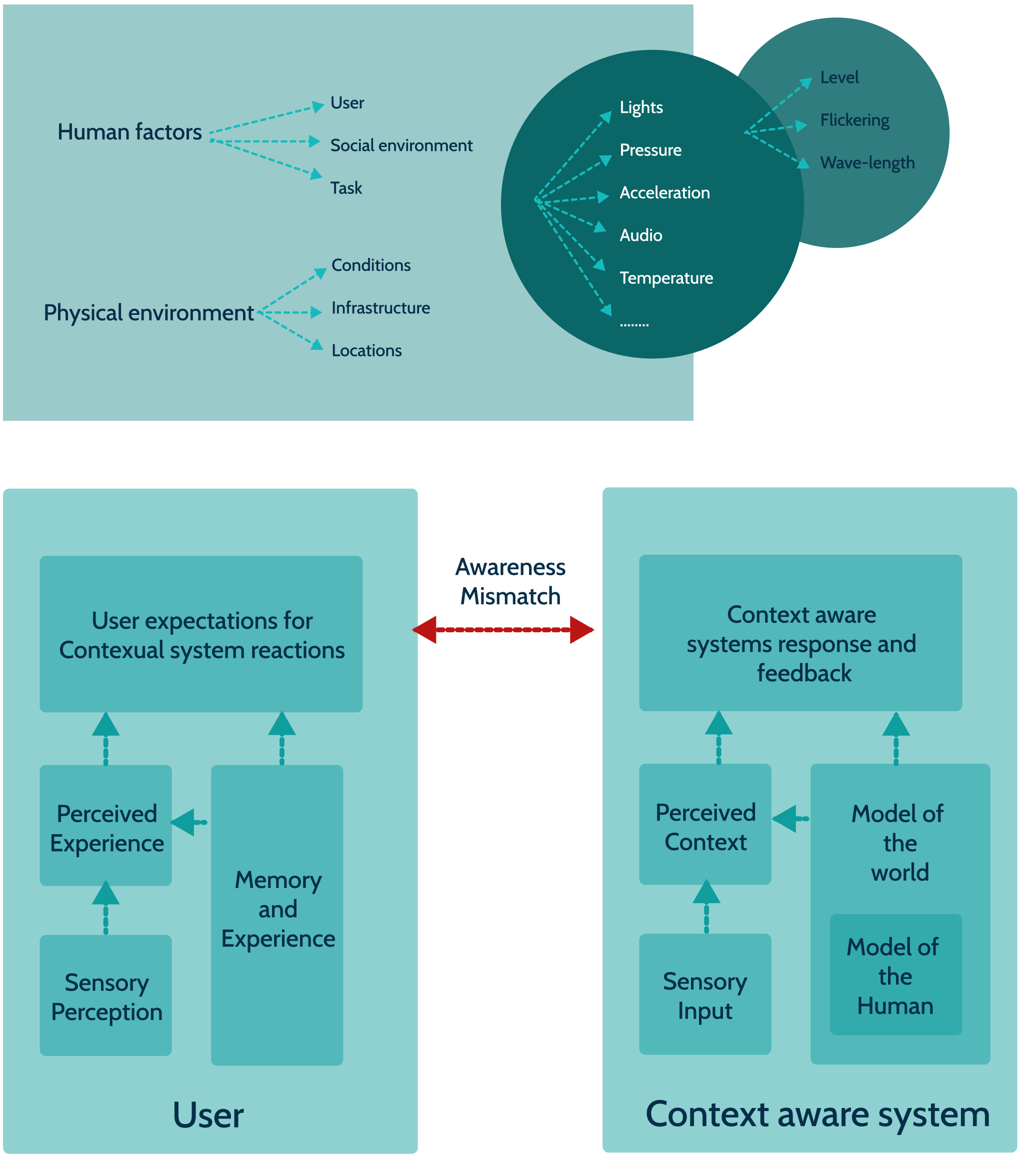


Fig 1.15: User-Context Perception Model (UCPM)

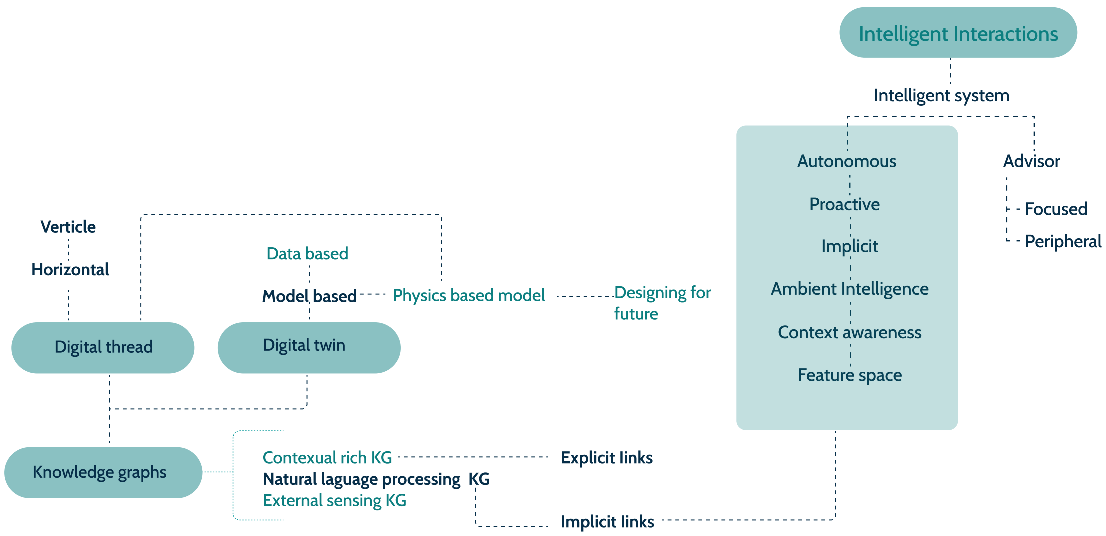


Fig 1.16: Overall mind map

In the overall mind map, I have tried to show all the related areas and highlighted my area of focus in blue.

1.6 Framework for interaction

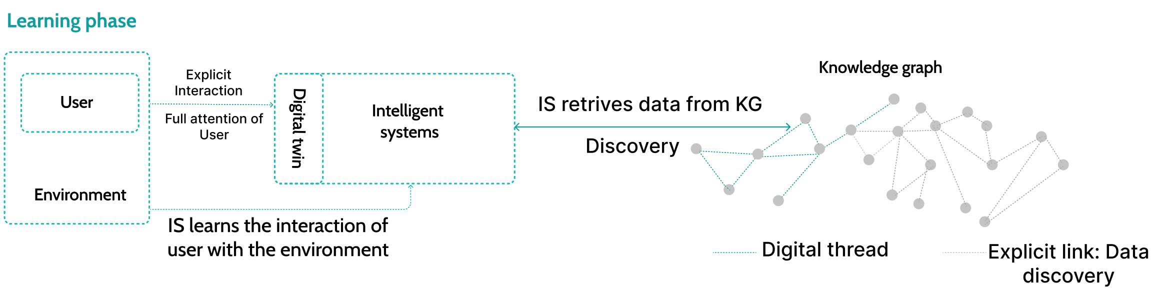


Fig 1.17: Learning phase

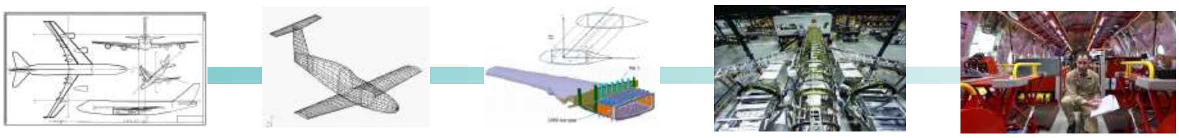
In the framework above, initially, an intelligent system learns from the environment. Then, the user interacts with the intelligent system and asks the system to fetch the information from the digital thread. During this interaction, the system learns from the exchange. Also, at this stage, IS helps in retrieving the data. It doesn't make any intelligent recommendation, it just understands the context of the search.

Fig 1.18: Intelligent recommendations/ augmentation

In the next stage, The intelligent system starts recommending the information to the user based on the search. This is where implicit interaction takes place. The system after understanding the context tries to group the related information into different groups.

Chapter 2

Aerospace engineers are mainly responsible for developing new technologies for aviation, defense systems, and spacecraft. The diagram below shows the aircraft journey map.
For my current project, my solution can mainly be used for the first three stages, especially solid modeling where the detailing of the entire aircraft begins. There are multiple considerations to be taken care of right from the size, and optimization to the material selection in this stage.



Conceptual sketching
It is in conceptual design that the basic questions of configuration arrangement size and weight, and performance

Preliminary design
Lofting: A key activity during preliminary design is "lofting." Lofting is the mathematical modeling of the outside skin of the aircraft with sufficient accuracy.

Solid modelling
Solid modelling of each component in detail. Cross domain collaboration takes place.

Production
The components are assembled, detailed working model of the actuators and flight control surfaces is assembled.

Flight testing
Flight simulators are developed and flown by both company and customer test-pilots

Area of focus for interaction with digital twin

2.1 RFLP Model

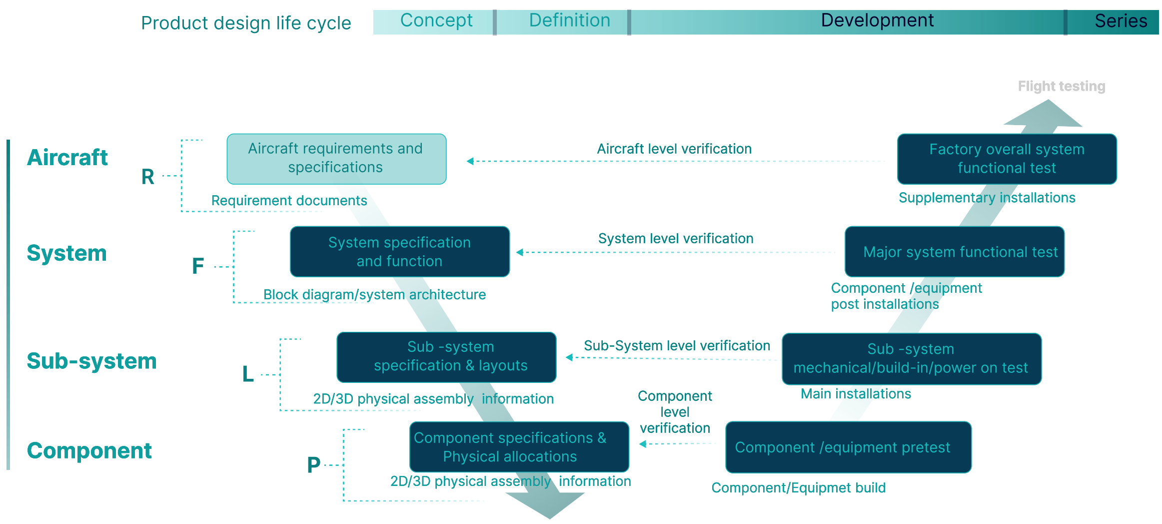


Fig 3.1: RFLP mode[15]

RFLP Model for aircraft design

Requirement, function, and logic programming steps are used for designing the aircraft and testing.

Currently, the system follows a top-down approach where the entire system is designed and decomposed till the component level of design, after the entire design process, the testing of the design happens step by step, this is represented in the form of V Model. The testing happens serially after the completion of the final design of the aircraft.

2.2 Hypothetical pain points

• High dependability- Preliminary design freeze is completely dependent on the aircraft designers.

• Overwhelmed with a lot of data- leading to multiple design considerations.

• Loss of time-current industry practice requires manual verification of the physical and functional integration, which is extremely labor intensive and requires expert knowledge of both aircraft systems and assembly planning.

• Reliability on self-experience and knowledge-Paper doesn't talk about predictive testing at the initial design stage, before freezing the preliminary design.

• Difficulty to collaborate

• No assured final design- Verification of the design is done from the component testing stage.[15]

Chapter 3

3.1 Ecosystem

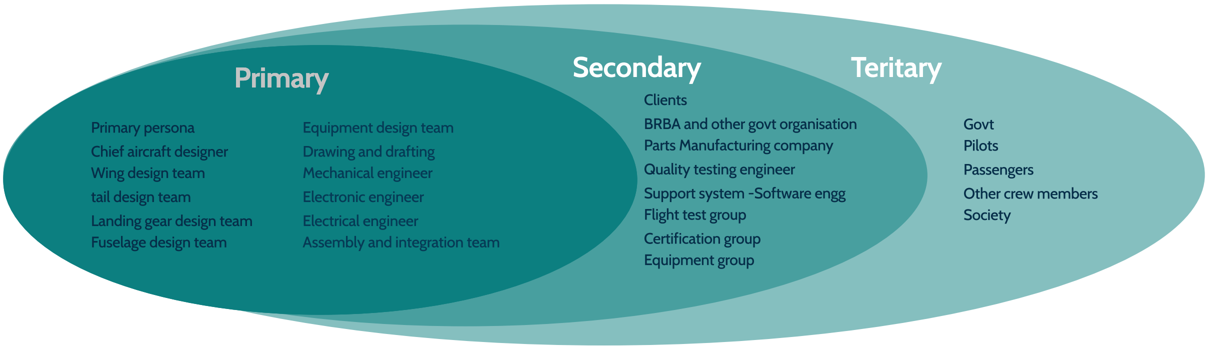
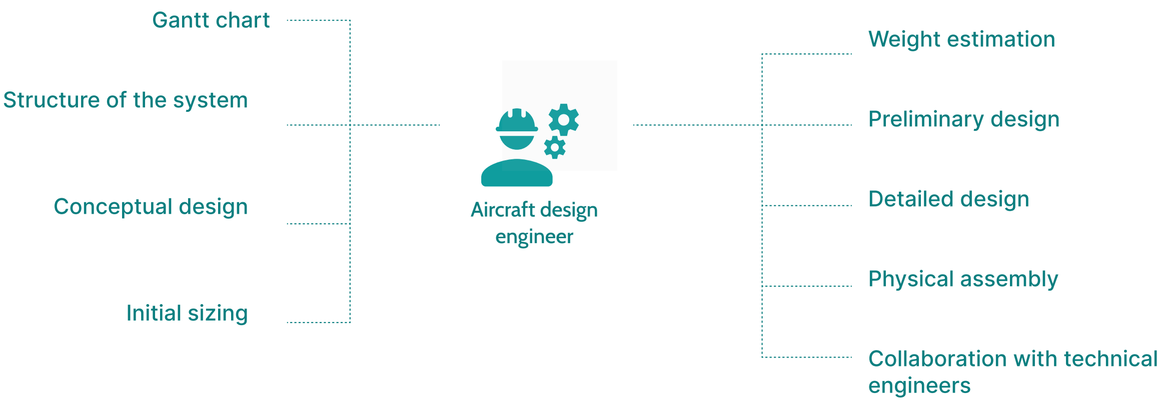


Fig 3.1: Ecosystem

The entire ecosystem is divided into a primary, secondary, and tertiary persona. The primary persona includes all the design engineers and mechanical and electrical engineers who were involved in the initial design process. The secondary persona includes clients and other teams who are indirectly involved in the design.

3.2 Who is an aircraft designer?

Aircraft design engineers develop, design, and test any new technology for the aircraft and Spacecraft. The diagram below represents the activities done by the aircraft designer.



3.3 Interview questions

1. Introduction(Brief)
2. How does the aircraft design happen?
3. Who is the different type of engineers involved in the design?
4. How do you normally test in the design stage?
5. How does the interaction happen between different teams?
6. How do you look for the information?
7. How long does it take to design the aircraft?
8. How many design iterations happen? When does the collaboration start?
9. How is the design verification done?
10. How do you check the efficiency of the new technology while modeling?
11. Do you have any AI-run predictions in the system? If yes what are they?
12. How much of your dependability is there while designing the system?

3.4 Insights

Most of the designers are trained to handle the overall design with less collaboration.
-Phil Grandy

High dependability on self-experience on knowledge

We cant finalize the design, it takes time. Only after physical testing the finalization happens
-Chimay Sawant

No Assured in design. Overloaded Information

We are not sure about the initial design in this case hence try to iterate it again and again.
-Phil Grandy

Self doubt while introducing new technology.

Sometimes, Designers cant easily collaborate with other technical engineers
-Chimay Sawant

Difficulty collaborating with other zones

We depend of predictions when we don't have any previous data regarding the same
-Phil Grandy

Human made Predictions are more.

Most of the time we do manual verification to trace back the values
-Chimay Sawant

Loss in time.

Sometimes it takes multiple iterations and we change parameter test value
-Phil Grandy

Unsure about the new design(When new design is Introduced)

We have multiple designers working on the same aircraft design
-Dhana lakshmi

Difficulty to collaborate

Very hard to find the exact resource online, most of the innovation happens within a company.
-Dhana lakshmi

Difficult to find resources online.

We depend on physical prototype testing in the case of new technology
-Dhana lakshmi

Loss of resources and money.

Most of the verification is done by the testing team, it's a very iterative process and takes a lot of time.
-Dhana lakshmi

Loss of time in the verification process.

We relay a lot on knowledge, if it doesn't work out we check the basic calculations and modify it further-
Dhana lakshmi

Cognitive load is increased.

Most of the innovation happens within a particular airline.
Dhana lakshmi

Very less access to information while testing new technology.

Quotes from interview | Insights derived | Finding

3.5 Persona

Arunima K

Fuselage designer
Age: 30 years
Education: Aerospace designer
Experience: 5 years

What does she do?

Arunima is responsible for designing the Fuselage of the aircraft where he calculates, fixing the requirements and detailing the components.

Tools used

Currently muiltiple softwares are used for designing aircraft.

- Shark CAD pro
- ADS
- Cart 3D
- CATIA

How does she use knowledge base?

- To design the seat chart
- Look at previous cabin data
- To check fuselage configuration
- To Design the Cockpit
- Understand Human dimensions and limit etc

Expectations

Arunima wishes to work in a ecosystem where colloboration with other peers is simple and she can get easy access to information.

Challenges

Overloaded with the information to take multiple things while designing.

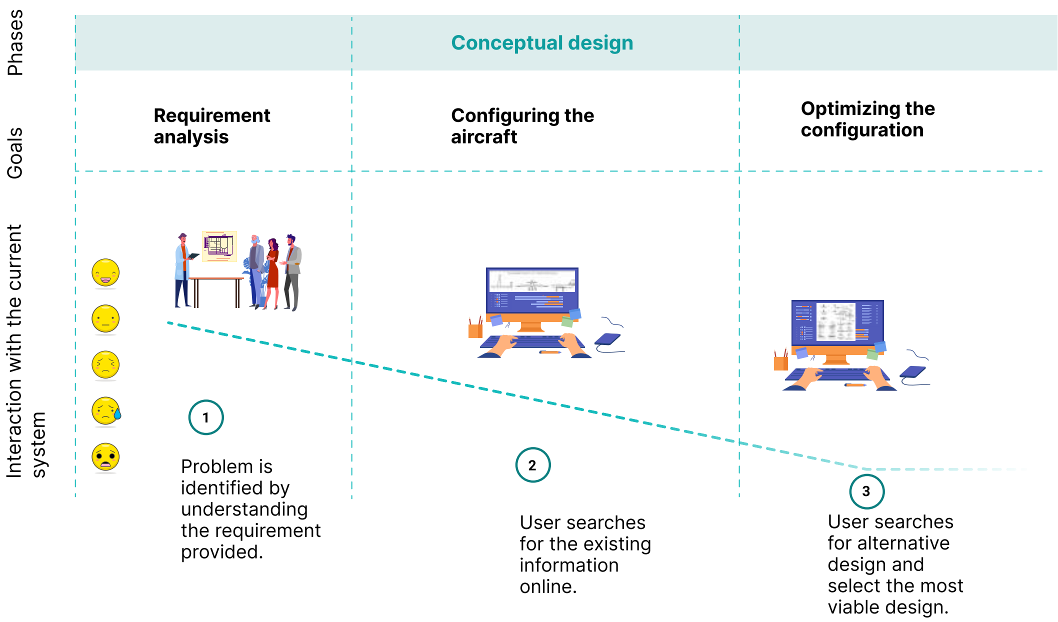
Manual verification needed individually for all the detailed design.

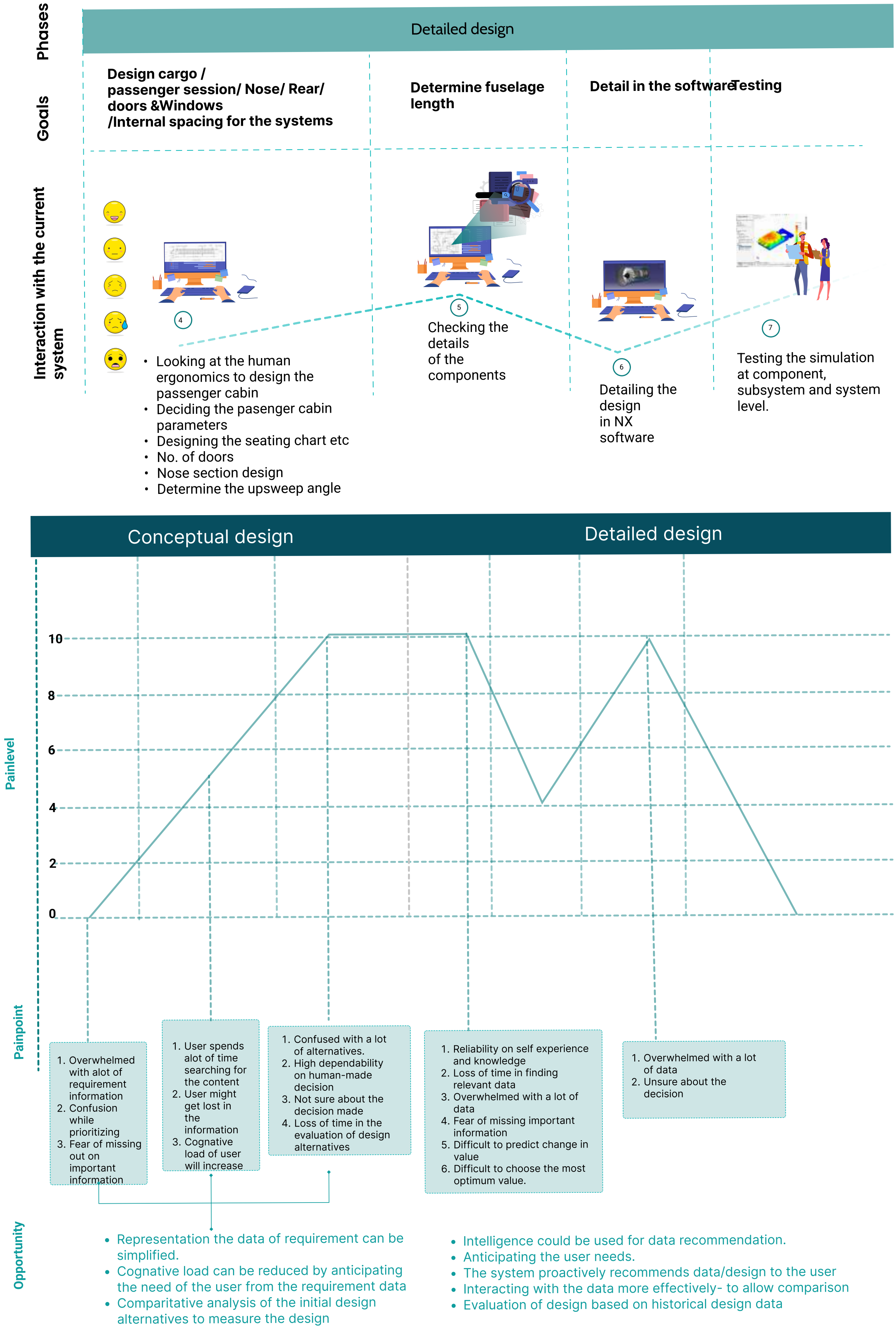
Understanding the right requirement and applying it while designing.

Multiple iterations while testing new technology in aircraft.

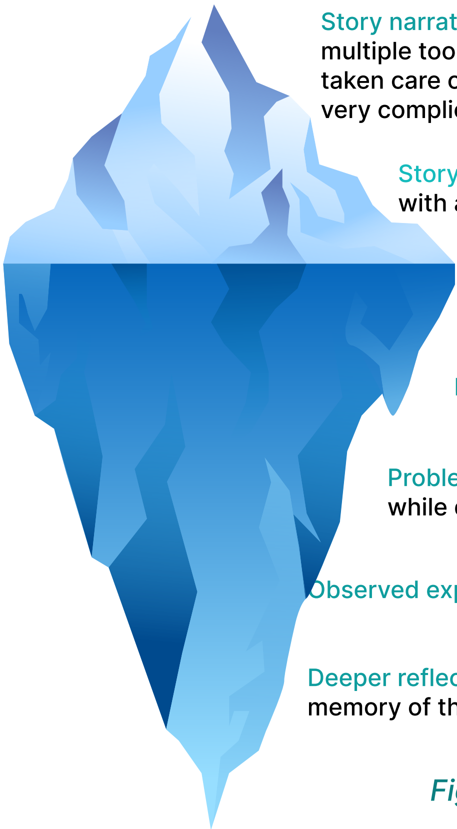
Fig 3.2: Persona

3.6 Journey Map




Phases
Detailed design
Goals
Design cargo / passenger session/ Nose/ Rear/ doors &Windows /Internal spacing for the systems
Determine fuselage length
Detail in the software
Testing
Interaction with the current system
4
• Looking at the human ergonomics to design the passenger cabin
• Deciding the pasenger cabin parameters
• Designing the seating chart etc
• No. of doors
• Nose section design
• Determine the upsweep angle
5
Checking the details of the components
6
Detailing the design in NX software
7
Testing the simulation at component, subsystem and system level.
Conceptual design
Detailed design
Painlevel
10
8
6
4
2
0
Painpoint
1. Overwhelmed with alot of requirement information
2. Confusion while prioritizing
3. Fear of missing out on important information
1. User spends alot of time searching for the content
2. User might get lost in the information
3. Cognative load of user will increase
1. Confused with a lot of alternatives.
2. High dependability on human-made decision
3. Not sure about the decision made
4. Loss of time in the evaluation of design alternatives
1. Reliability on self experience and knowledge
2. Loss of time in finding relevant data
3. Overwhelmed with a lot of data
4. Fear of missing important information
5. Difficult to predict change in value
6. Difficult to choose the most optimum value.
1. Overwhelmed with a lot of data
2. Unsure about the decision
Opportunity
• Representation the data of requirement can be simplified.
• Cognative load can be reduced by anticipating the need of the user from the requirement data
• Comparitative analysis of the initial design alternatives to measure the design
• Intelligence could be used for data recommendation.
• Anticipating the user needs.
• The system proactively recommends data/design to the user
• Interacting with the data more effectively- to allow comparison
• Evaluation of design based on historical design data

Tip of the ice berg



Story narrated- Reality check: When designing aircraft, multiple tools are used, multiple designs considerations are taken care of which and this makes the process of designing very complicated for the end users.

Story Understood- Design engineer -designing-Frustrated with a lot of data- Loss of time- may achieve the goal

Purpose- Design and iterate new technology faster and easier

Need- Reduce the cognative load of the designer

Problem- There are overloaded information to be considered while designing.

Observed experience- Anxiety+ Acute pressure+Stress

Deeper reflection- Anticipating- mental model -Experience- memory of the design

Fig 3.3:Tip of ice berg

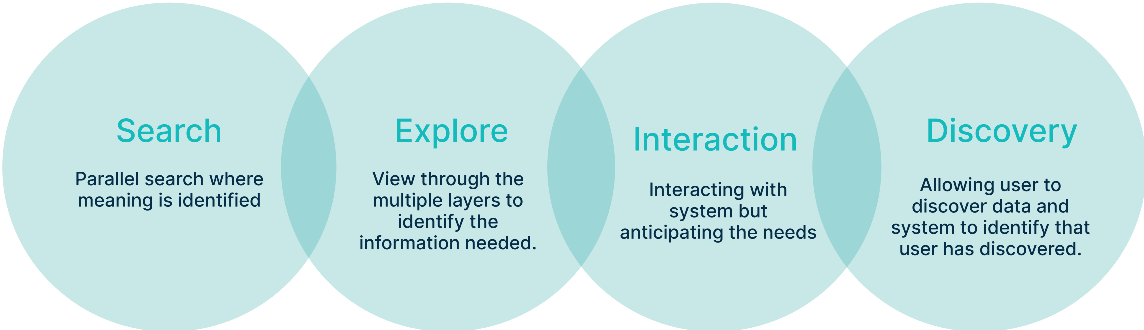
3.7 Redefined brief

How might we improve the experience for design engineers while using aircraft information from multiple resources for designing the components of the aircraft?

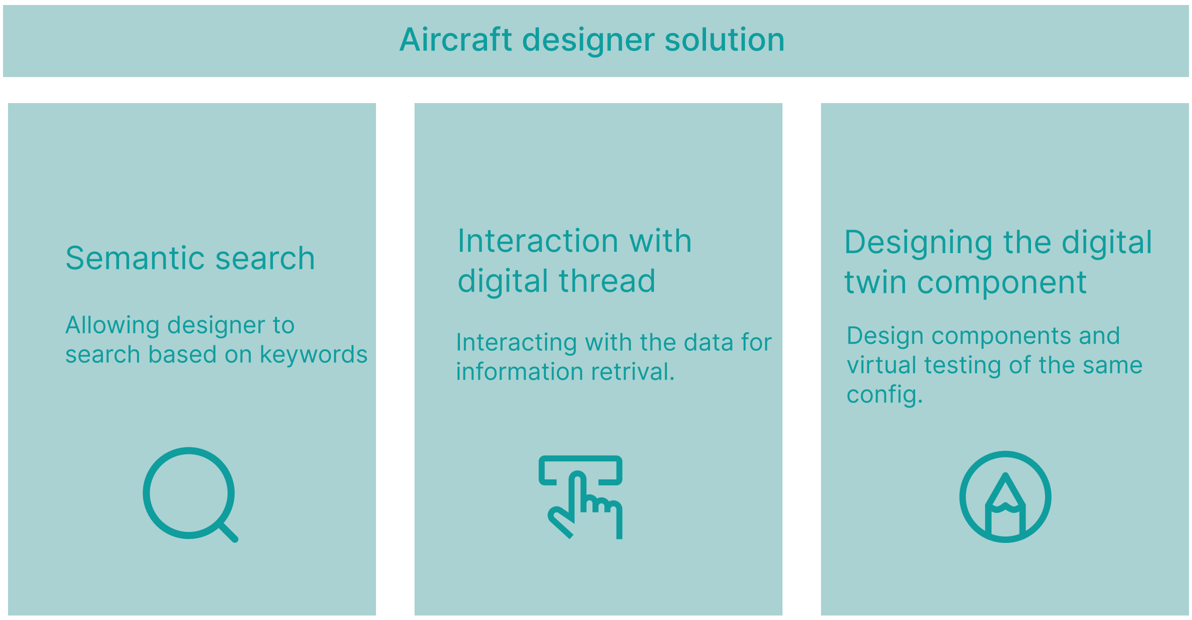
Make experimentation of aircraft design easier.	Use connected information efficiently.	Allow intelligent interaction between humans and systems(Implicit interaction)	Provide assured design.

Chapter 4

4.1 Bifurcating Concept



4.2 Solution direction



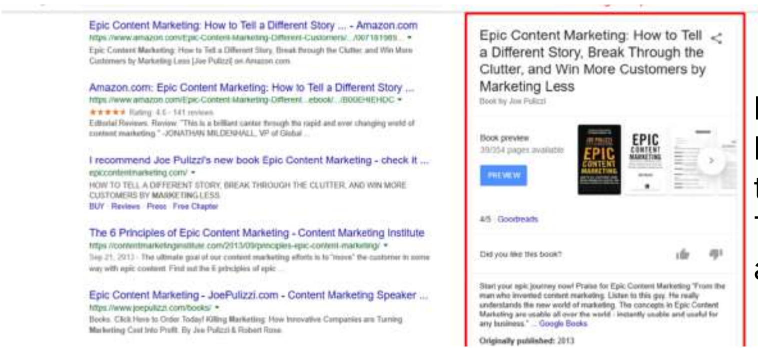
For ideating, I divided my project into three parts.

- **Semantic search-** ways in which user can search in the system
- **Digital thread representation-** ways to represent digital thread for user to interact with.
- **Interaction with thread vertically and horizontally-**Ways in which user can interact with digital thread

4.3 Ideation

Ideation 2:
Part 1: Semantic search
The first step is to start searching, I tried to research and understand how search can take place.

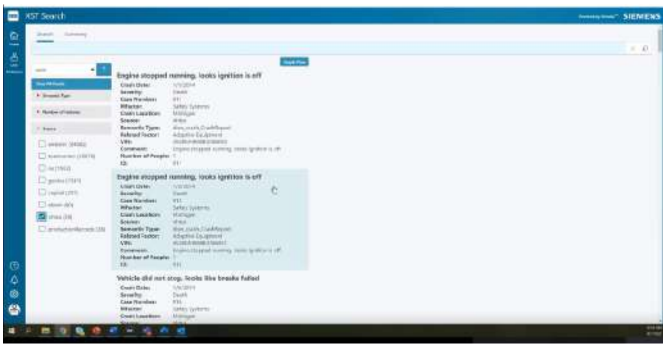
Google search



List view
Most related data is shown in the top
The website link I displayed with a small brief

Fig 4.1 Google search

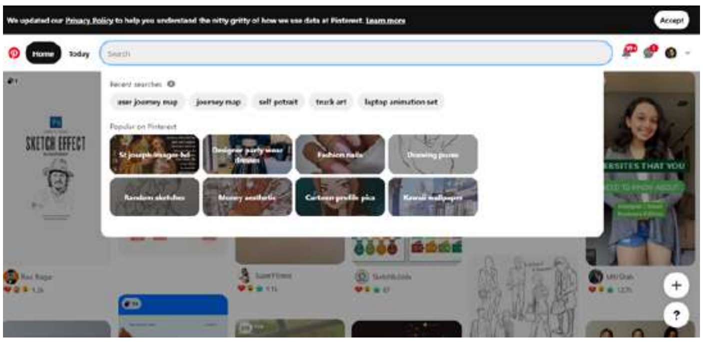
Siemens XST Database



List view
It shows the information, according to the input given by the user. Here all the records with * are shown to the user.

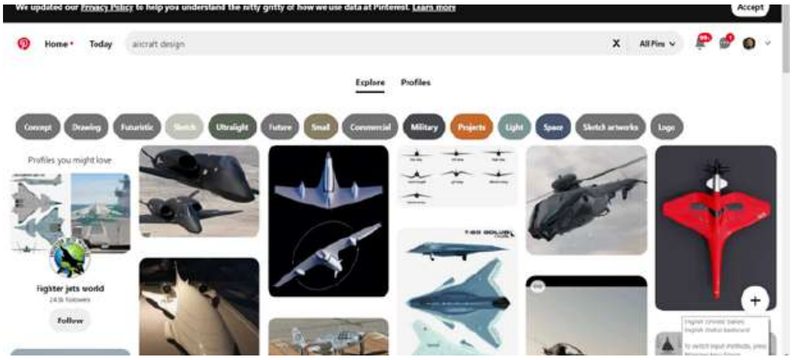
Fig 4.2 XST Database

Pinterest



Anticipatory design,
It recommends to the user what he looking for.

Fig 4.3 Pinterest

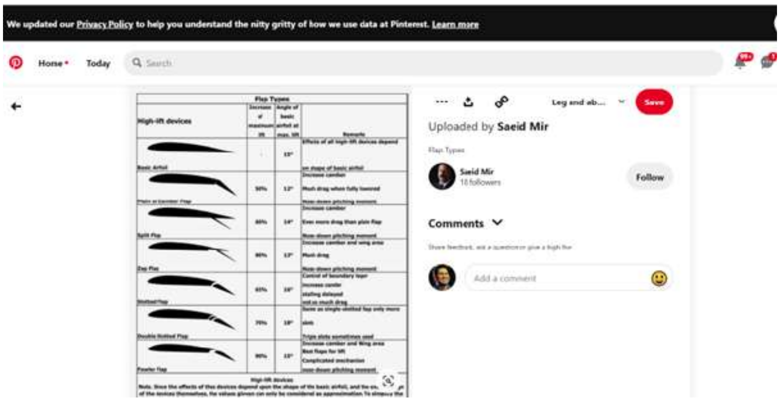


Shows more related areas (Similar to google images)

Fig 4.4 Pinterest

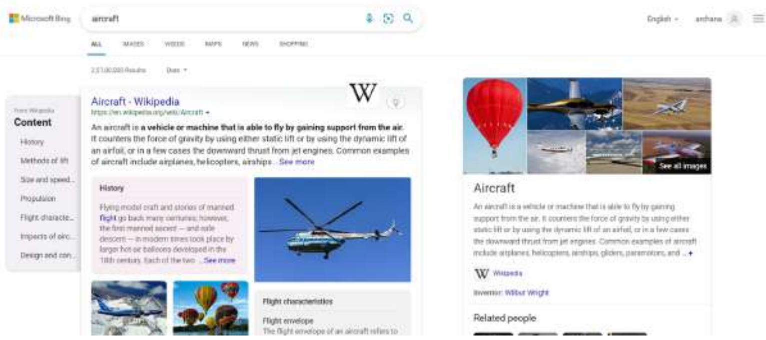
Shows the content of the aircraft(Related field) in the form of an image

Fig 4.5 Pinterest



Gives a description of the image-Details of the image(Who published, ULR, etc)

Fig 4.6 Pinterest



Shows content similar to google. Establishes content bar on the left for easy navigation.

Fig 4.7 Microsoft Bing

4.4 Ideations for search:

Search representation 1:

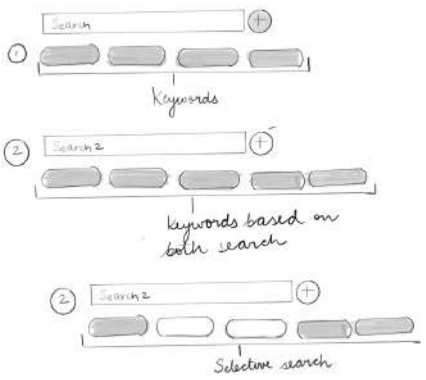


Fig 4.8 Search Representation 1

When the user knows what he is searching
Scenario-Designer searching for Mig-26 fighter Aircraft that crash-landed in Punjab.
Idea 1-

- User searches the text as mentioned above
- System will identify the search and represent.
- User can do a selective search by unselecting the
- Keywords, the number of information shown will increase

Search representation 2:

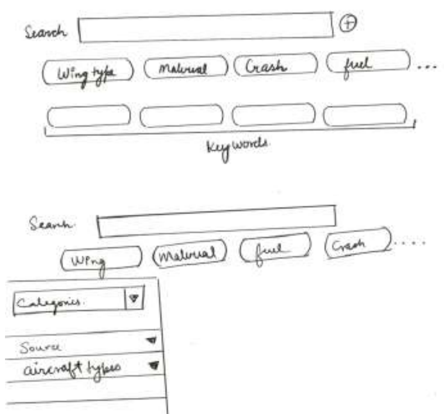


Fig 4.9 Search Representation 2

When the user knows what he is searching
Scenario-Designer searching for Mig-26 fighter Aircraft that crash-landed in Punjab.
Idea 2-

- User searches the text as mentioned above.
- User can select the subgroups for filtering or as shown below user can click on the filter button.
- System will identify the search and represent.

Search representation 3:

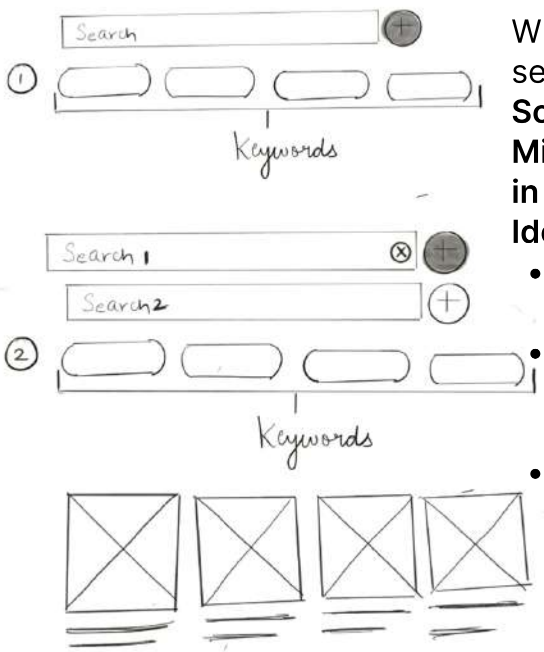


Fig 4.10 Search Representation 3

When the user knows what he is searching
Scenario-Designer searching for Mig-26 fighter Aircraft that crash-landed in Punjab.
Idea 3-

- User searches the text as mentioned above.
- User can add another search and connect them both parallelly, by clicking on add button.
- Search can be represented in the form of keywords or images.

Search representation 4:

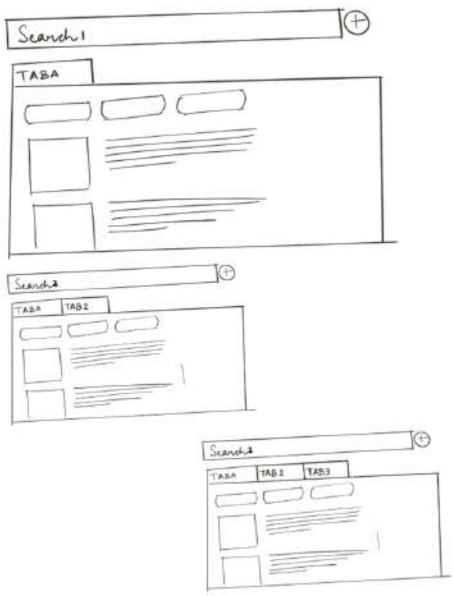


Fig 4.11 Search Representation 4

When the user knows what he is searching
Scenario-Designer searching for Mig-26 fighter Aircraft that crash-landed in Punjab.
Idea 4-

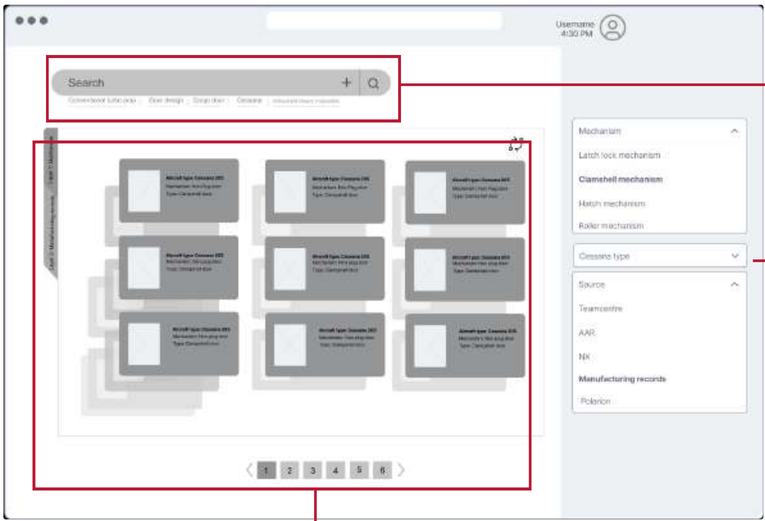
- User searches the text as mentioned above.
- User can represent each search as TAB A and TAB B and so on.
- Search from tab A to tab B will be connected. If search of tab A has to be removed then close tab A.

Finalizing the search:

After explorations, I decided to go with the search representation two. The reasons are:

- The current XST database also has similar search technique, hence it will fit the mental model of the user.
- It will be easier for probing user when there are huge number of results from database.
- It illustrates Hicks Law, which reduces the decision making time.

Refining the concept further in the form of wireframes:
Idea 1:



User Initially searches information,
user can add search.

Implicit Interaction through filter bar: Based on the input given by user, system will prompt user to make the next decisions based on the context of search.

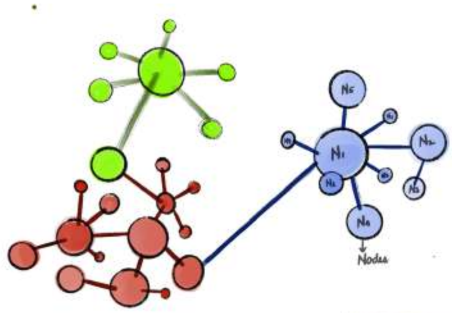
Fig 4.12 Idea

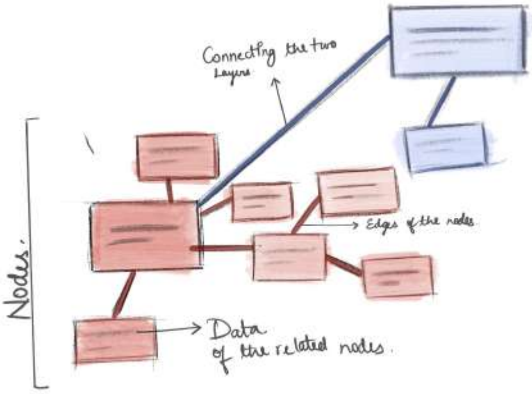
Search ideation will appear as Tabs on the side, user can go to different layers by clicking on the tab.

4.5 Ideations for node representation:

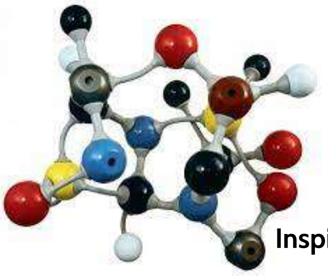
01

Molecular cluster





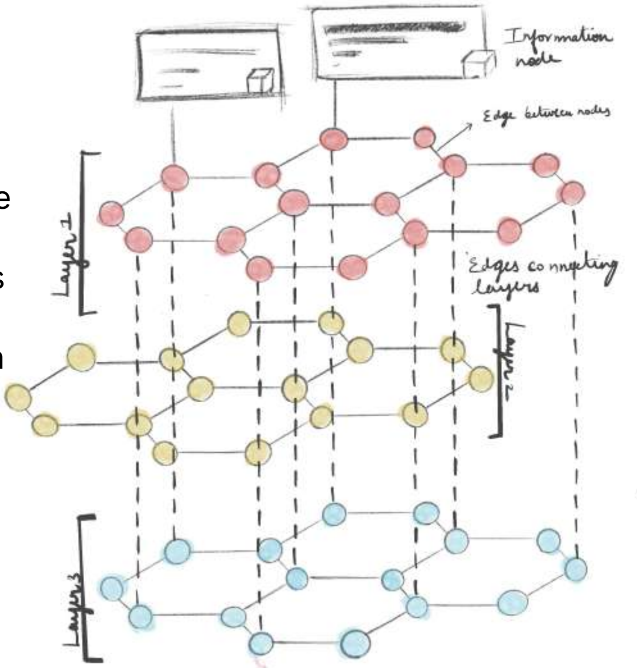
The molecular cluster used the concept of a covalent and ionic bond to represent the data. The inter-data bond is represented as a covalent bond and the bond between two exclusive layers is called an ionic bond. Data will be structured in the form of the molecule for 3d interaction.



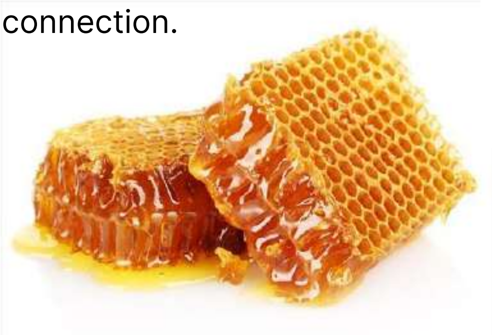
Inspiration: Molecule

02

Hive layer



Inspired by the layered structure of honeycomb. Each corner represents the data node that is connected to other nodes. The layers are attached through the edge. There are 2 kinds in them. Each layer represents a topic and the connection between them is a cross-layer connection.

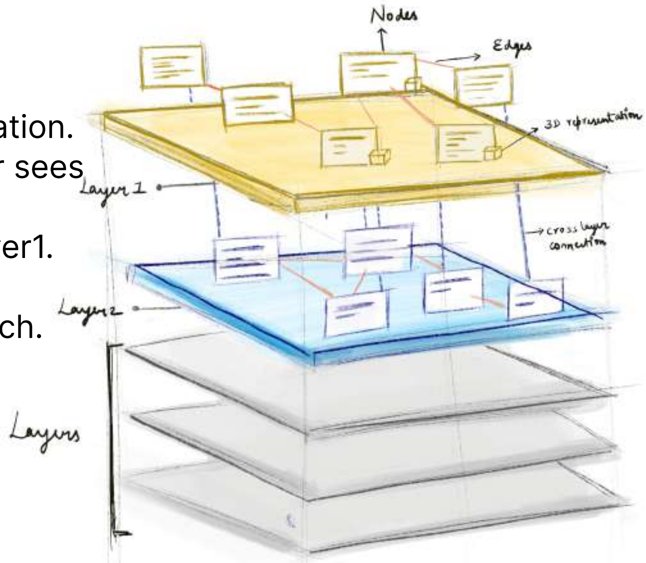


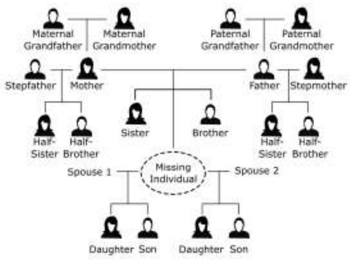
03

3d cluster tree

The 3d cluster tree is mainly uses relative and priority-based information. depending on the search, the user sees layers of information, the one with the highest priority appears on layer1.

Layers are built based on the search.

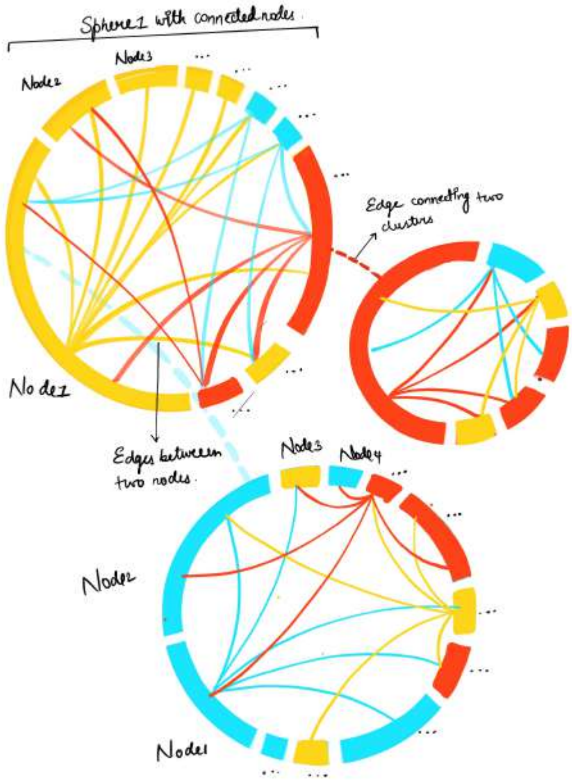




04

Cluster pattern

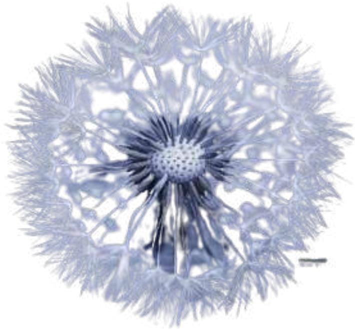
The cluster layer is inspired by the embroidery pattern. Each layer is represented as a circle, and a circle has multiple nodes. Each node is linked based on the information searched. Between two layers there are cross-connections.

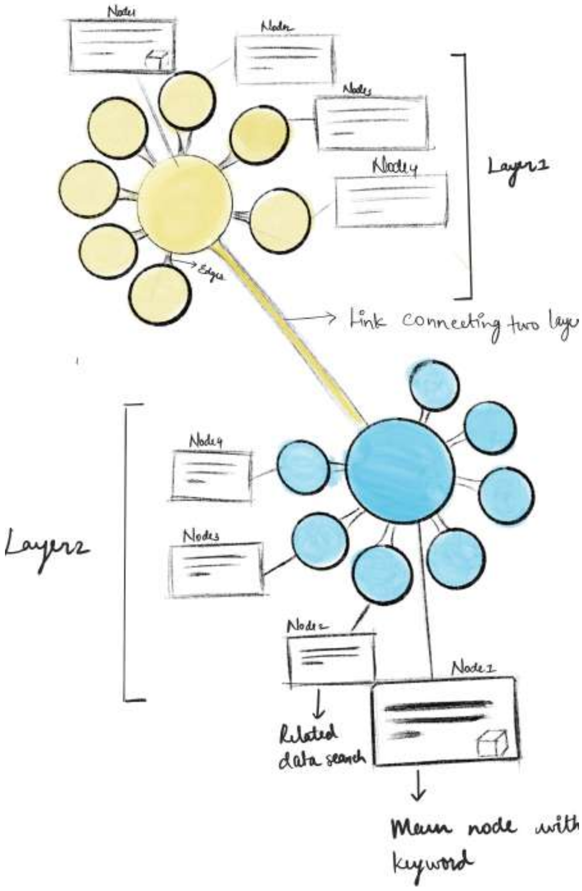


05

Cross pollen

Inspired by the pollen, each pollen has multiple petals, and this is represented in the form of nodes. There is going to be a crosslink between the pollens as presented in the diagram on the left.
Colors and used to show the representation of data nodes. The main node is presented in the center

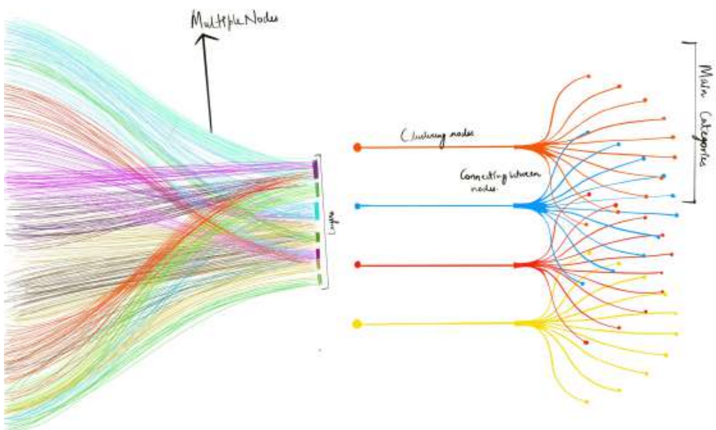




06

Nerve end

The human nervous system is composed of multiple nerves which merge with the spine. Similarly, I have created multiple spines for the data information. This is a very interesting way of representing the data information as it shows the data in a very simpler form. Data identification is made simpler with colors.



4.6 Finalization

	Navigation	Interaction	Understandablity	Ease of connection	Enjoyable	Recovery
Molecular cluster	Medium	Hard	Hard	Medium	Mostly	Hard
3D Cluster Tree	**Easy**	**Medium**	**Easy**	**Medium**	**Mostly**	**Easy**
Hive layer	Easy	Medium	Hard	Medium	Not sure	Hard
Cluster pattern	Hard	Hard	Hard	Hard	Not sure	Hard
Cross pollen	Hard	Hard	Hard	Medium	Mostly	Hard
Nerve end	Hard	Hard	Hard	Medium	Not sure	Easy
Connect cube	Medium	Hard	Hard	Hard	Mostly	Hard
Wheel layered	Easy	Medium	Medium	Medium	Not sure	Easy

Fig 4.13 Finalizing the solution

Node represetation
Type 1

Inspiration- Family tree

Features-
- 360 degree rotatable nod
- Preview of the files
- Details imprinted on the surface.
- Nodes arranged in the form of layers

Fig 4.14 Node Representation 1

Node represetation
Type 2

Inspiration- spherical representation

Features-
- 360 degree rotatable node
- Preview of the files
- Details imprinted on the surface.
- Nodes arranged in the form of layers

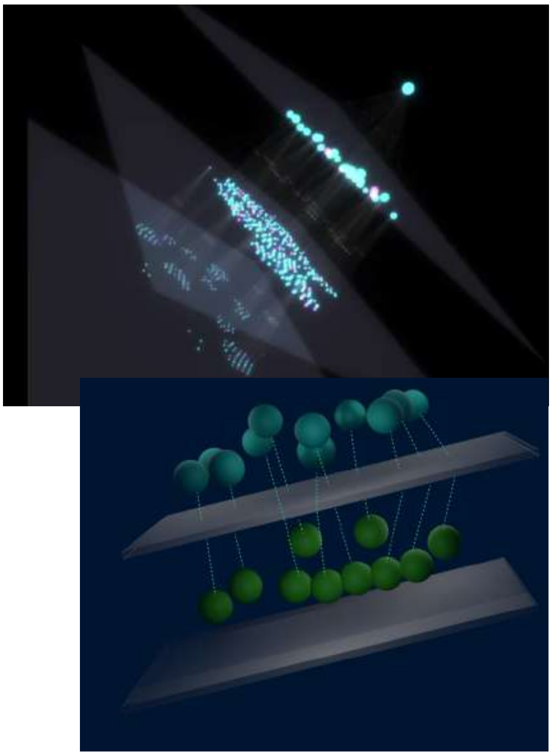


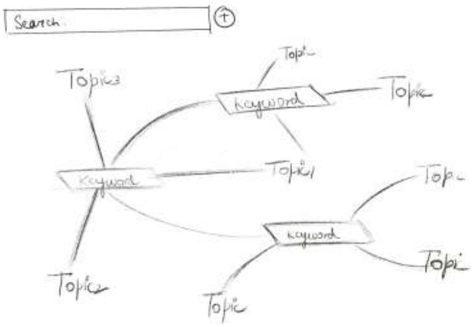
Fig 4.15 Node Representation 2

For the final project, I decided to focus on type one of the node representation.

4.7 Interaction with the digital thread

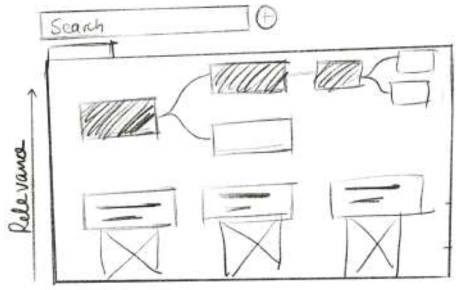
I mainly explored how the interaction with digital thread can take place.

Exploration:



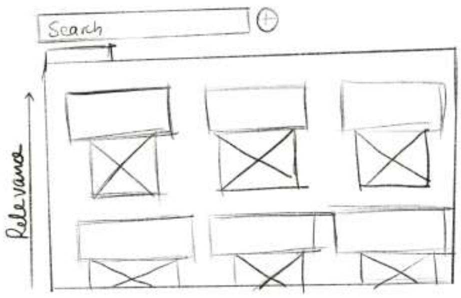
Idea 1:

Each node is represented in the form of a map, and this map is navigated step by step. The related nodes have common edges. If the user wants to check all the related nodes, they need to tap on the node.



Idea 2:

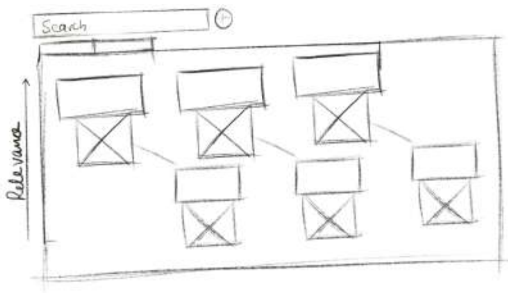
Use simple keyword matching while semantic search. User will be able to see the related node and the representation below.



Idea 3:

Use Tab representation for each node as shown in the previous ideation of the search. The information will be represented according to relevance.

Idea 4:



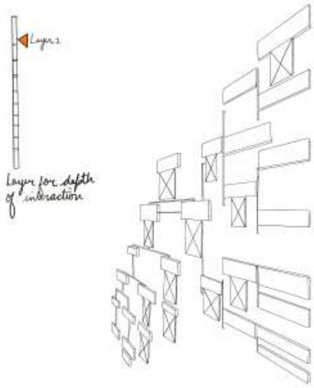
Nodes and the related node will be represented in an organized way. Each of these nodes will be represented in the form of layers and for the final solution, I considered this interaction.

Fig 4.16 Interaction with digital thread

Exploring through the digital thread.

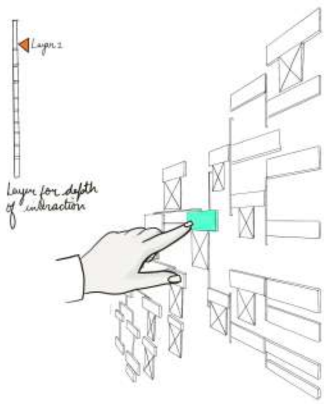
01 **Parallel search**

Understand the synonym and relationship between words and concepts, allowing you to find nodes on the topic.



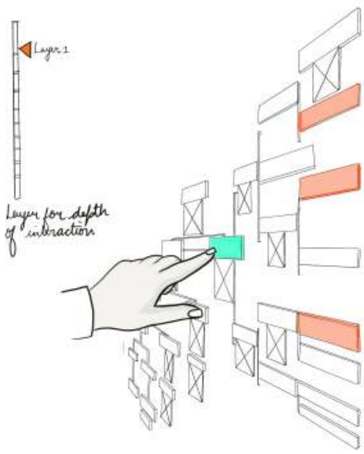
02 **3D Cluster nodes**

.Layer 1: initial search of the user is made available, and the user can explore the data nodes.URL, Supporting image to identify, Author.



03 **Exploring the nodes**

Layer 1 Interaction: User interacts with data.



04 **Interaction with system**

Layer 1 recommendation: System recommends the data to user.

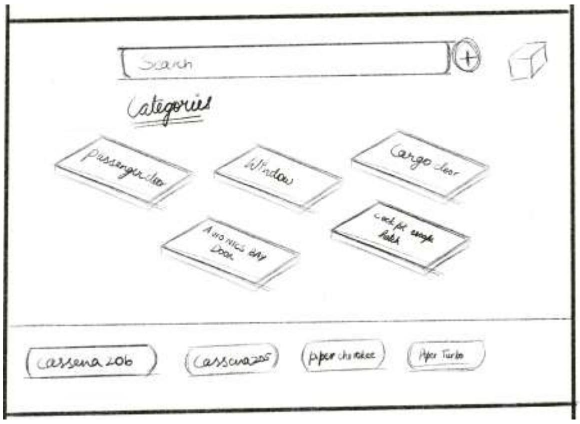
Fig 4.17 Exploring digital thread

4.8 Creating a scenario

Scenario: Designer is designing the fuselage of the turboprop in detail. First he starts designing the doors.

Step 1

- User: I want to know more about the door designs. Let me check the doors used in conventional turboprops.
- Search: Door type used in Cessna 206.

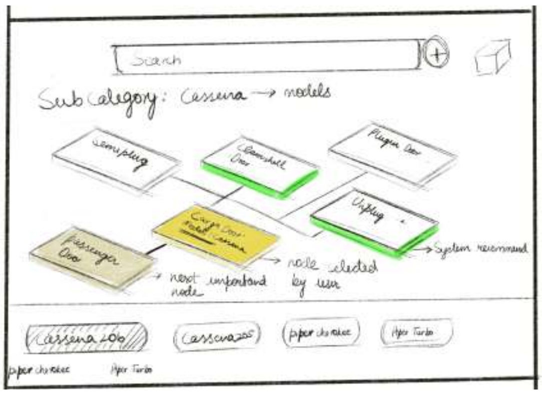


- System: Categorizes the doors into different broad types, to make the search easier.
- The lower bar represents the related search: So right now the user has searched the door types for Cessna 206, and the system suggests similar model aircraft for the user.

Fig 4.18 Step 1-Search categories

Step 2

- User : Let me check the cargo door types.
- **Search: user taps on the cargo door type.**



- System: Categorizes the cargo doors into different broad types, to make the search easier. The yellow tile the selected tile, green is the recommended next stage of navigation for the user by the system, and brown is the related search.
- The lower bar represents the related search: So right now user has searched the door types for cassena 206, system suggests similar model aircraft for user.

Fig 4.19 Step 2 System Recommendation

Step 3

- User : Let me check the nonplug door type
- **Search: user taps on the mechanism.**

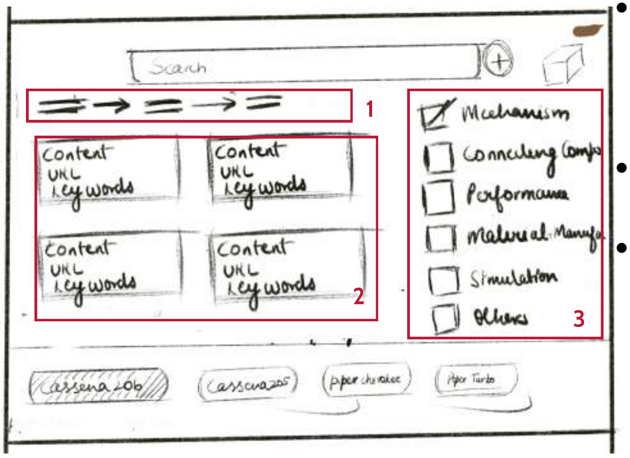


Fig 4.20 Step 3 Node representation

- System: There are a lot of nodes, and these nodes are arranged in different categories(check boxes) for easier search.
- 1- Breadcrumbs showing navigation
- 2-Nodes arranged showing the relevant content, URL, keywords from search(Right now it shows all the searches in the mechanism in non plug type doors)
- The lower bar represents the related search: So right now a user has searched the door types for cassena 206, the system suggests similar model aircraft for the user.

Step 4

- User : I want to know about the manufactures who manufactur type A
- **Search: user taps on addionally material and manufaction**

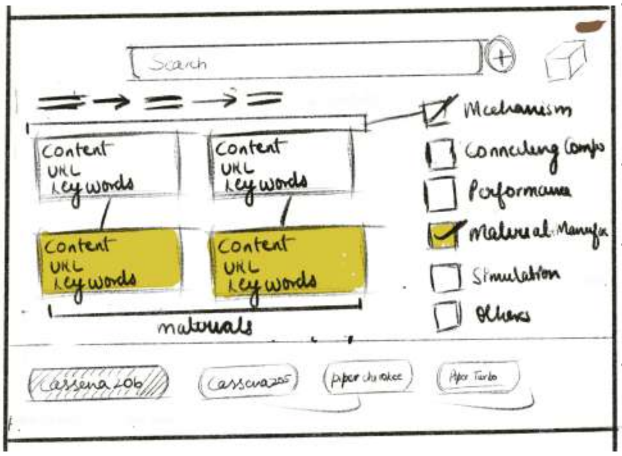
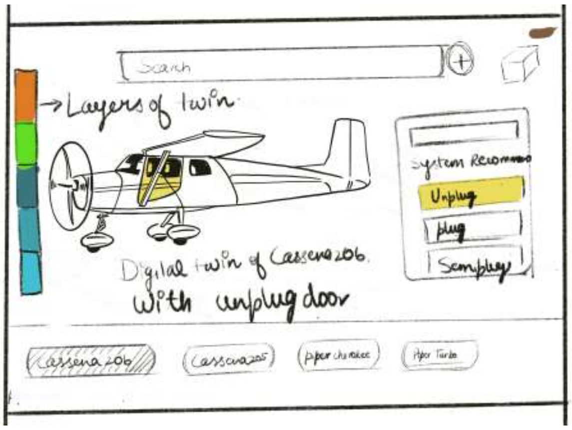


Fig 4.21 Step 4 Digital thread formation

- System: Connects the type A mechanism and all the manufacturers who manufacture it.
- 3-Layering of the nodes is based on
- Mechanism- All information sites showing the non plug door mechanism
- Connecting components- what are the components in this door, like fitting, electrical, mechanical, etc..

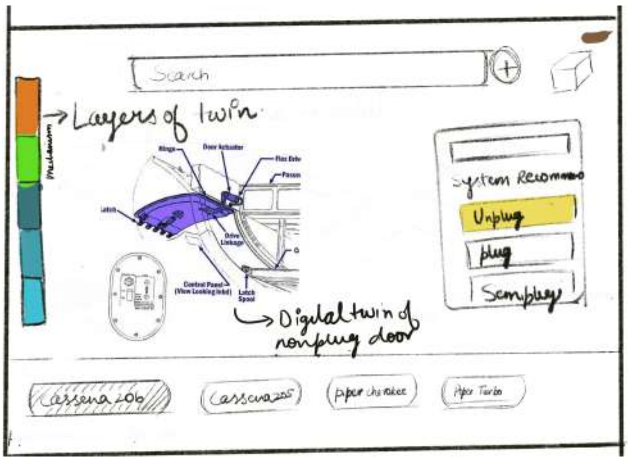
Step 5

- User : How will be type A non plug door look in my model
- **Search: user taps on 3d twin of the cassena 206 on top**



- Layering- In 3d twin layers are shown.
- Layer1-Components(Electrical+Electronic)
- Layer2-Mechanism
- layer 3-Manufacturing
- Layer 4-materials
- Layer 5-Performance

Fig 4.22 Step 5 Model analysis



System: shows the Cassena 206 digital twin with Nonplug door.

Layering- In 3d twin layers are show.
Layer1-Components(Electrical+Electronic)
Layer2-Mechanism
layer 3-Manufacturing
Layer 4-materials
Layer 5-Performance

Fig 4.23 Step 6 Model analysis

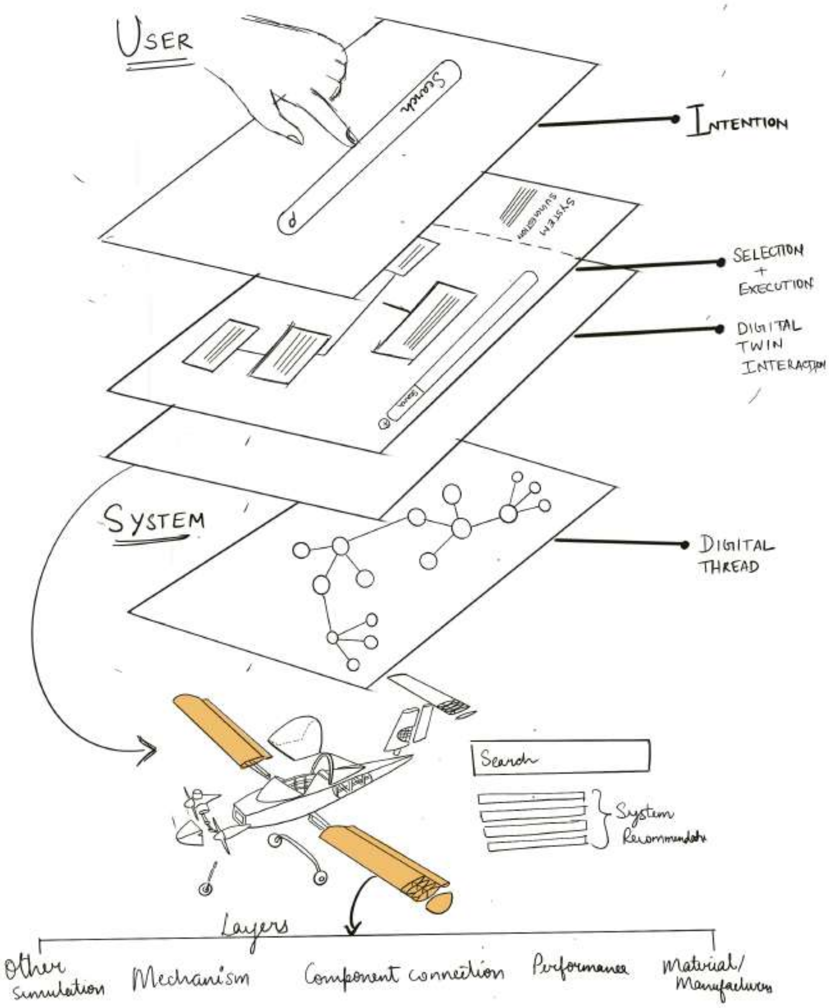


Fig 4.24Overall concept

- User: Forms Intention
- Intelligent system: Organises the information for the search from the digital thread.
- User: Selects
- System: Executes
- System: Suggests user by understanding the context of the search
- User: Gets the required information and builds a twin

4.10 Solution brief

What?

Enhance the experience of interacting with digital twin and Digital thread for designing aircraft components.

Who?

Aircraft design engineers

How?

Creating a VR/ Desktop medium for interacting with a digital thread information to create a twin.

4.11 Proposed Interactions with Digital thread

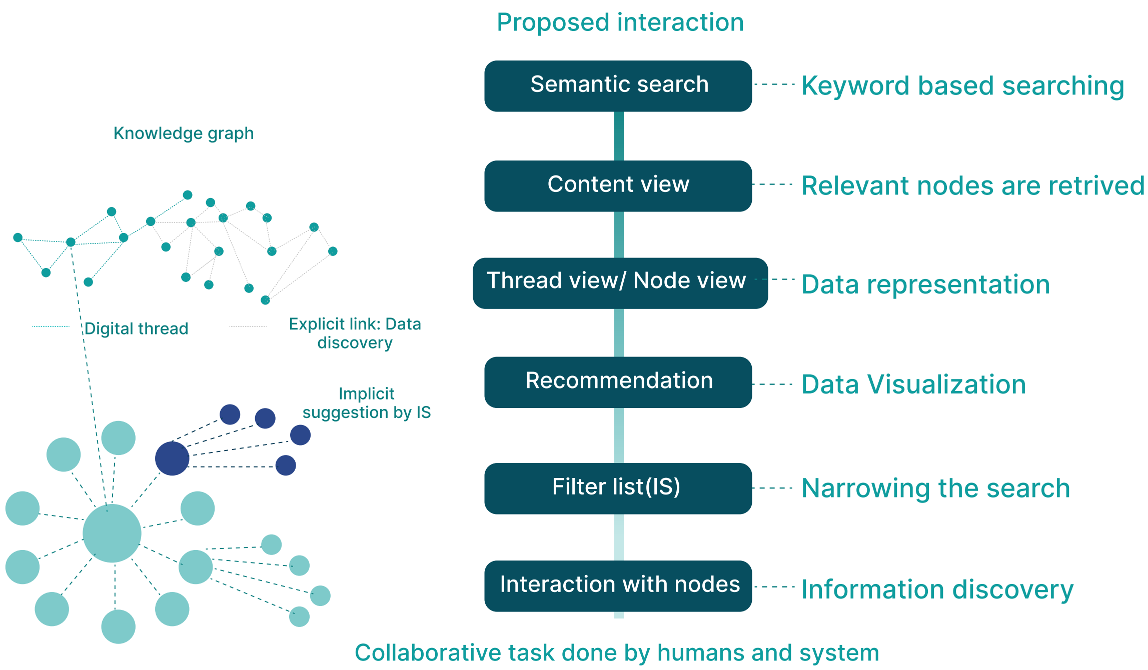
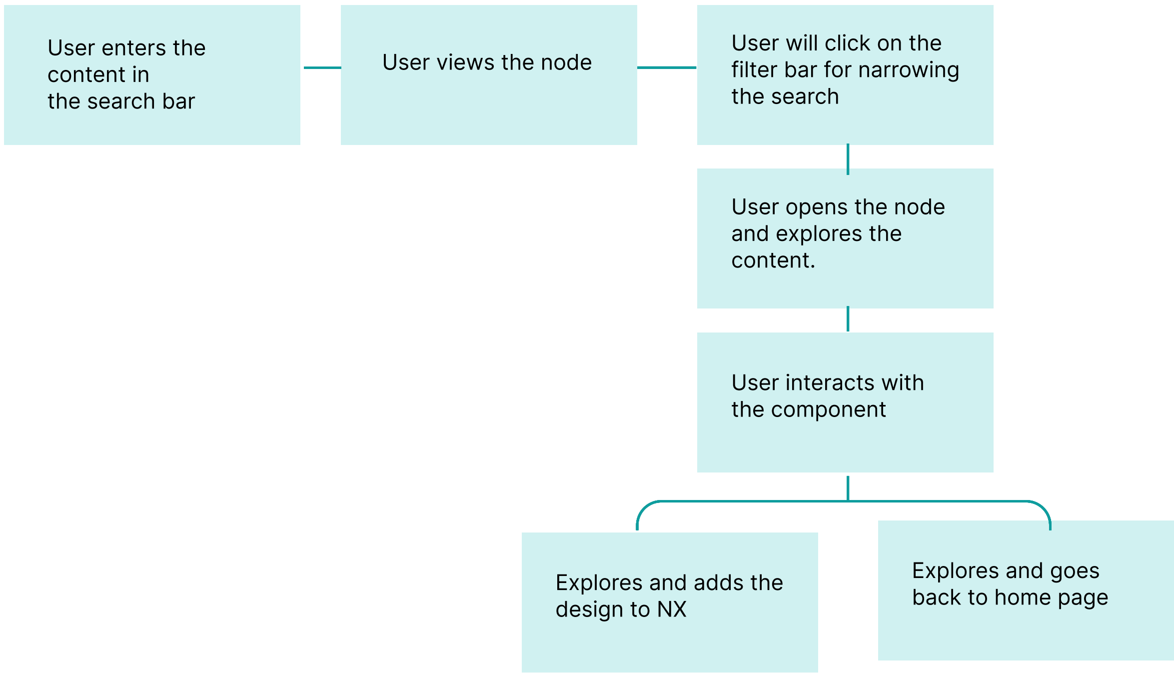


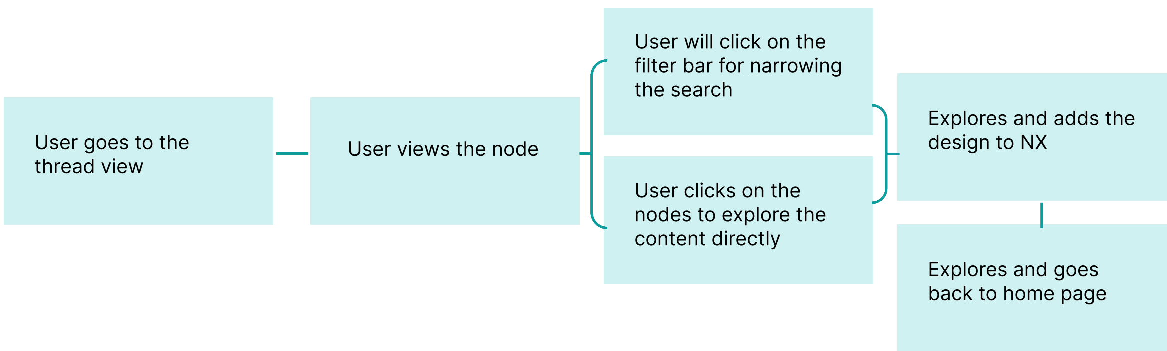
Fig 4.25: Interaction with digital thread

4.12 Task flow

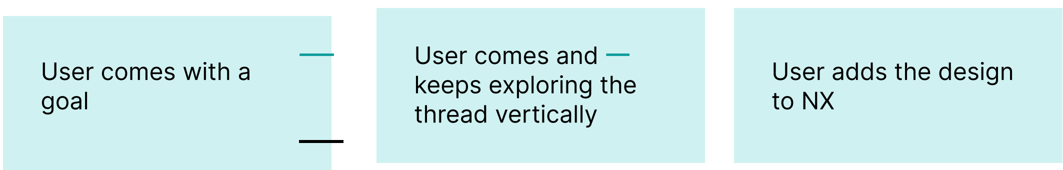
Scenario 1: User explores doors of Cessna (Exploration)



Scenario 2: User interacts with the digital thread



Scenario 3: User interacts for adding design to NX



Chapter 5

5.1 Wireframes

For the given project, I have not constructed any information architecture, and the reason because it represented a search engine. There were two variations of the solution constructed and they are represented below.

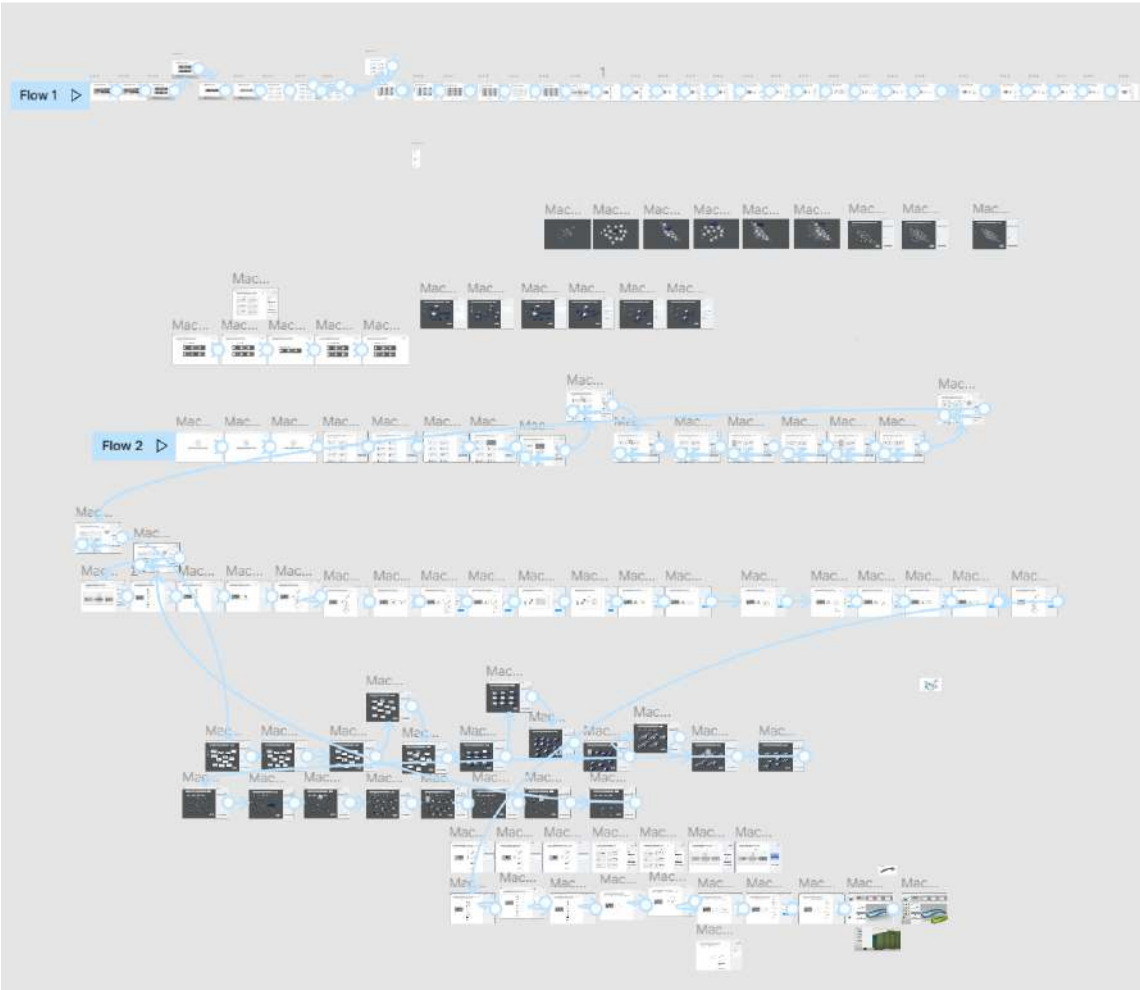


Fig 5.1: Wireframes

5.2 Visual Laguage

The visual language was taken and inspired from the design system of siemens, and it is in line with the visual design of siemens products.

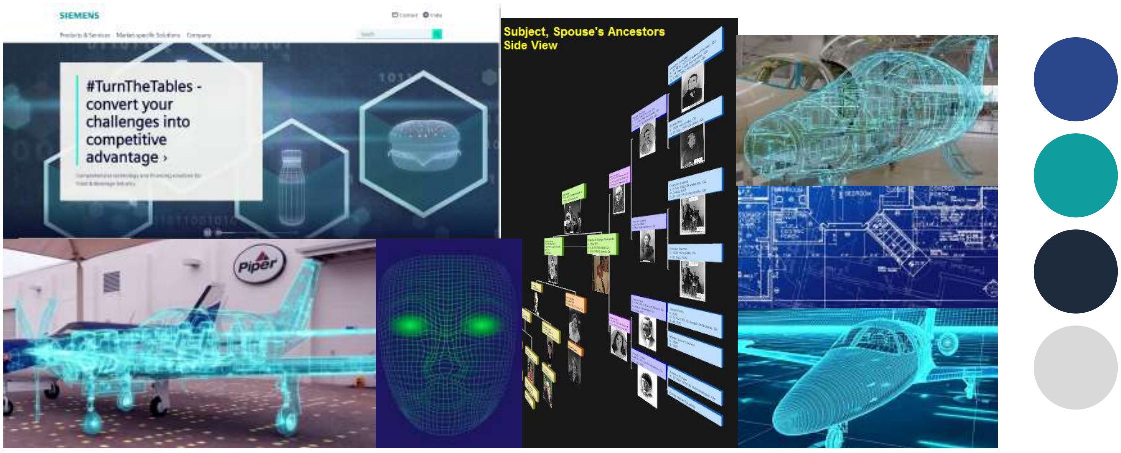


Fig 5.2: Moodboard

Type face

Aa Aa **Aa**

Regular Semi bold Bold

Inter Regular (12)

Inter bold (12)

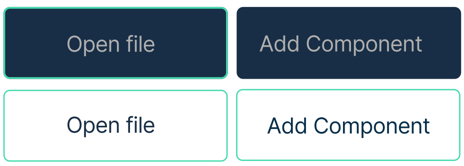
Inter bold (14)

Inter Regular (18)

Inter semi bold (18)

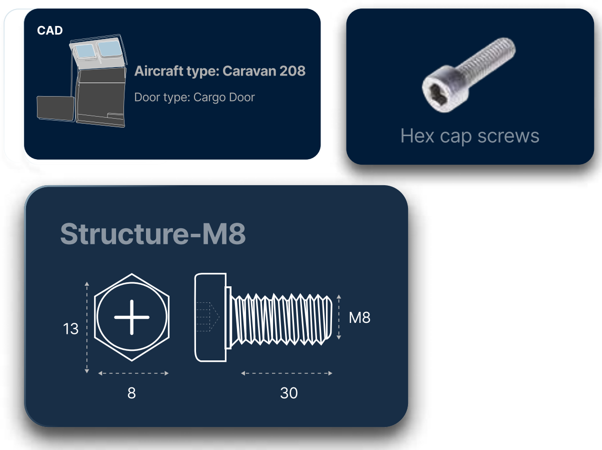
Inter bold (18)

Buttons



Icons

Node representation



5.3 High fidelity screens

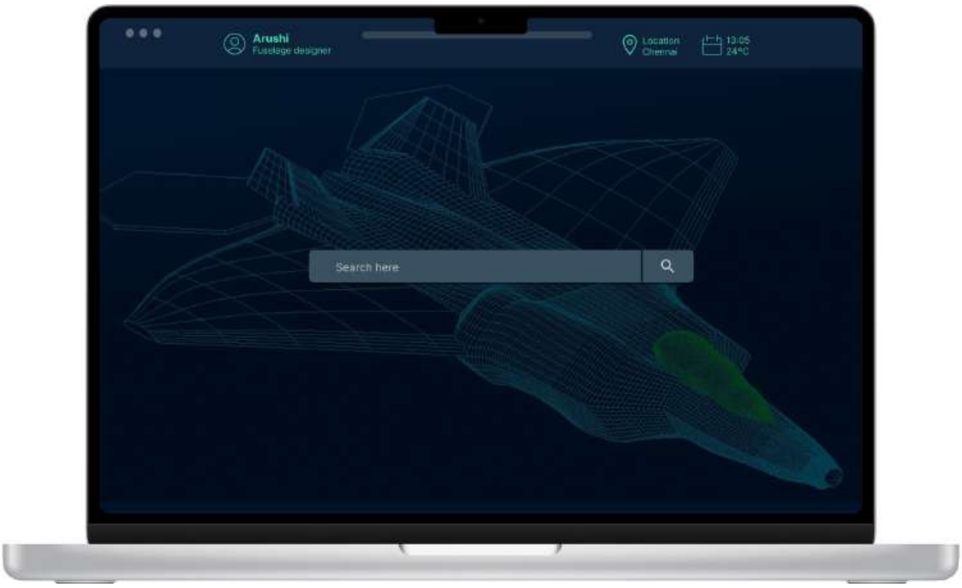


Fig 5.3: Search screen

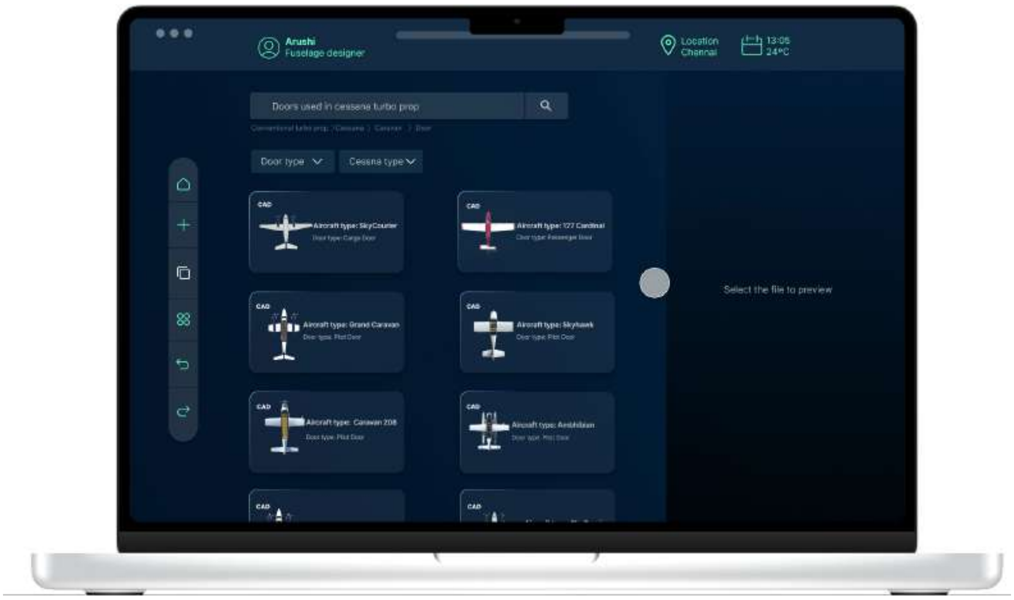


Fig 5.4:Screen showing all the aircraft type

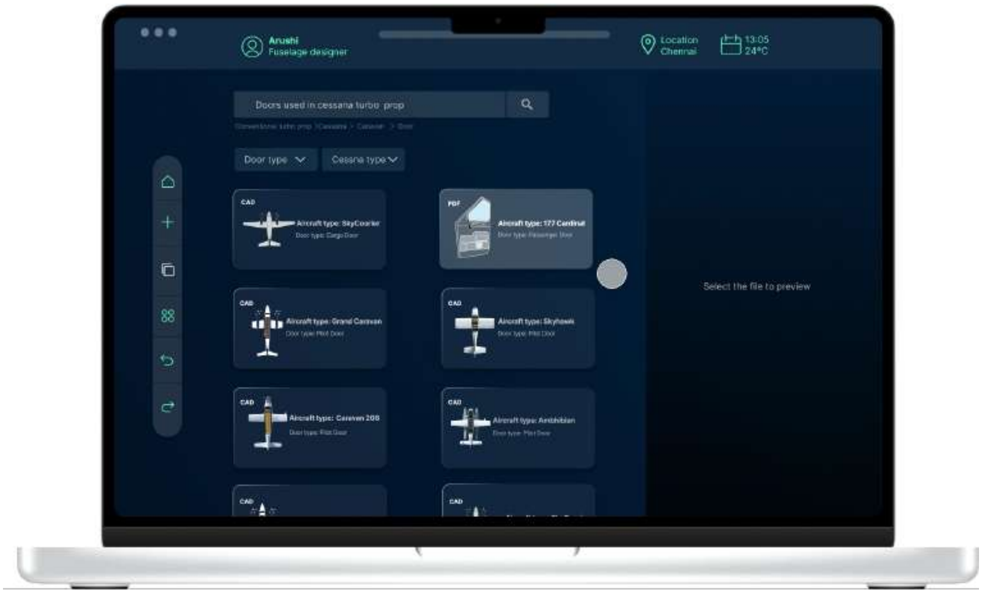


Fig 5.5:Hovering to show two informations in one layer

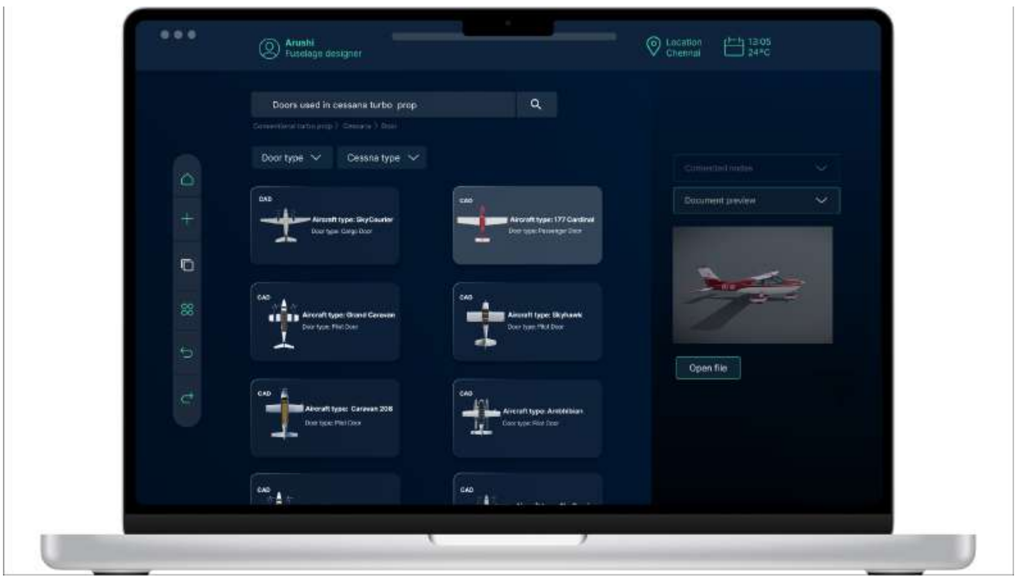


Fig 5.6:Showing the document details in the preview

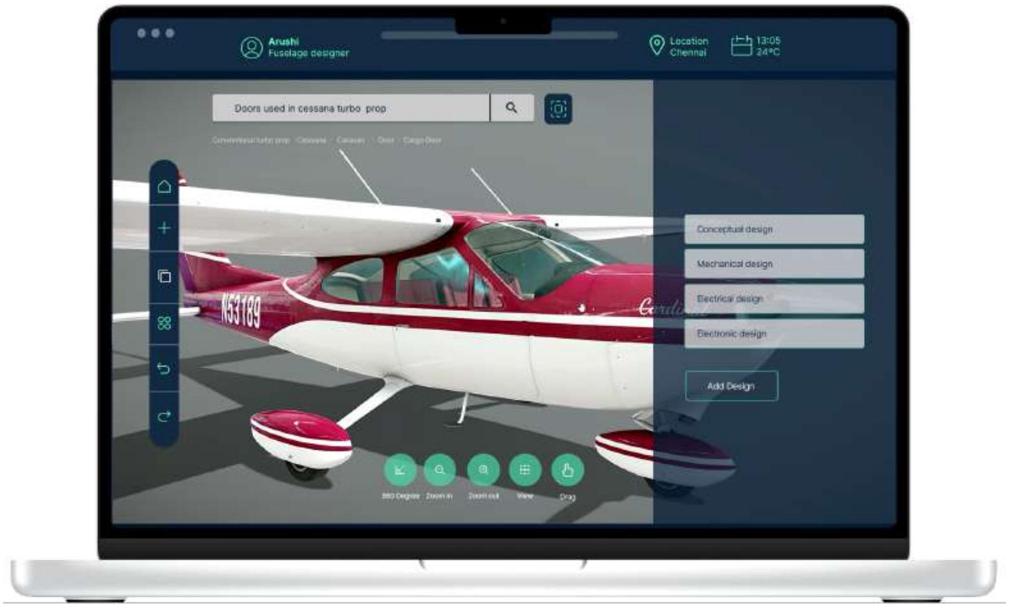


Fig 5.6:Interacting with the digital model of aircraft

Fig 5.7:Interacting with the digital model of aircraft

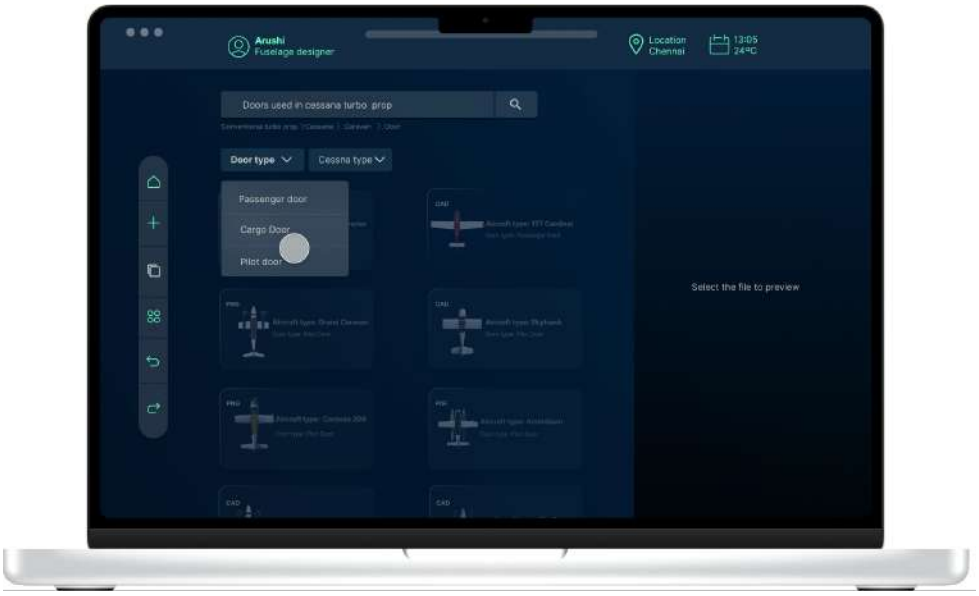


Fig 5.8:Implicit interaction: System asking user about the door type

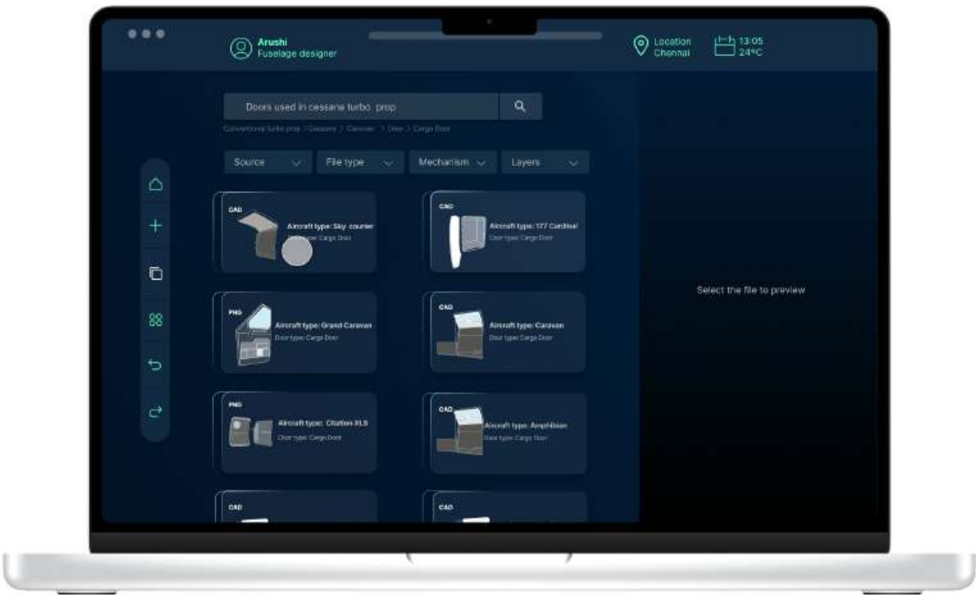


Fig 5.9:Layers forming:When user selects the cargo door

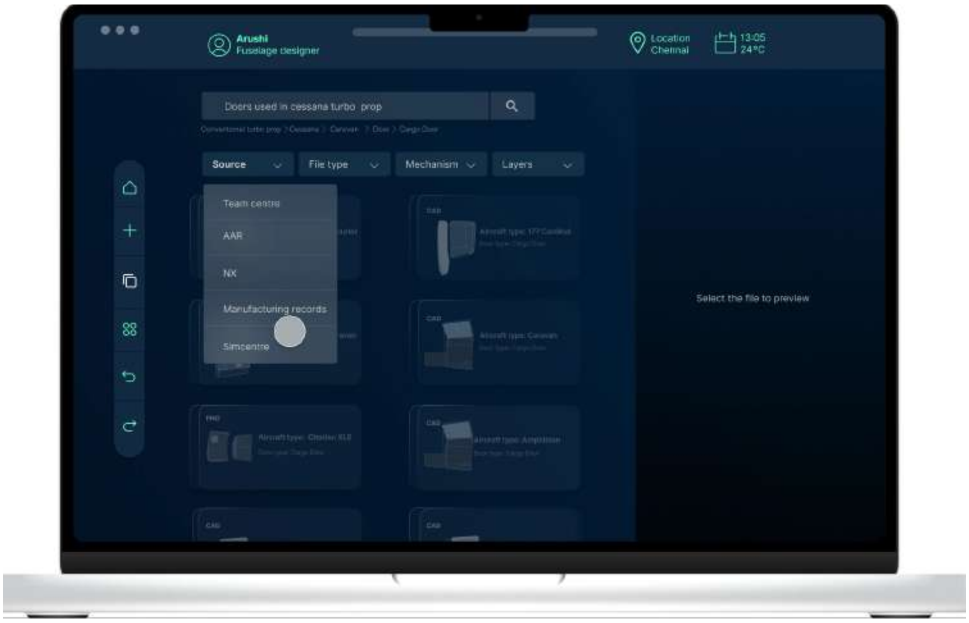


Fig 5.10:Implicit Interaction: User selecting the source

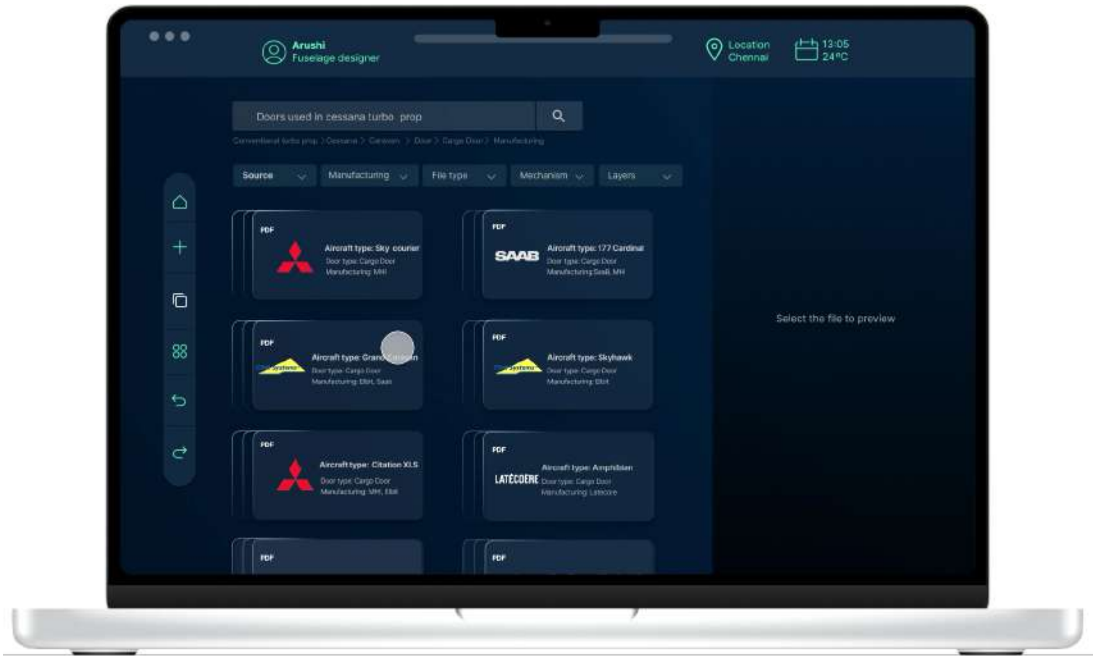


Fig 5.11:Sytem forming the third layer

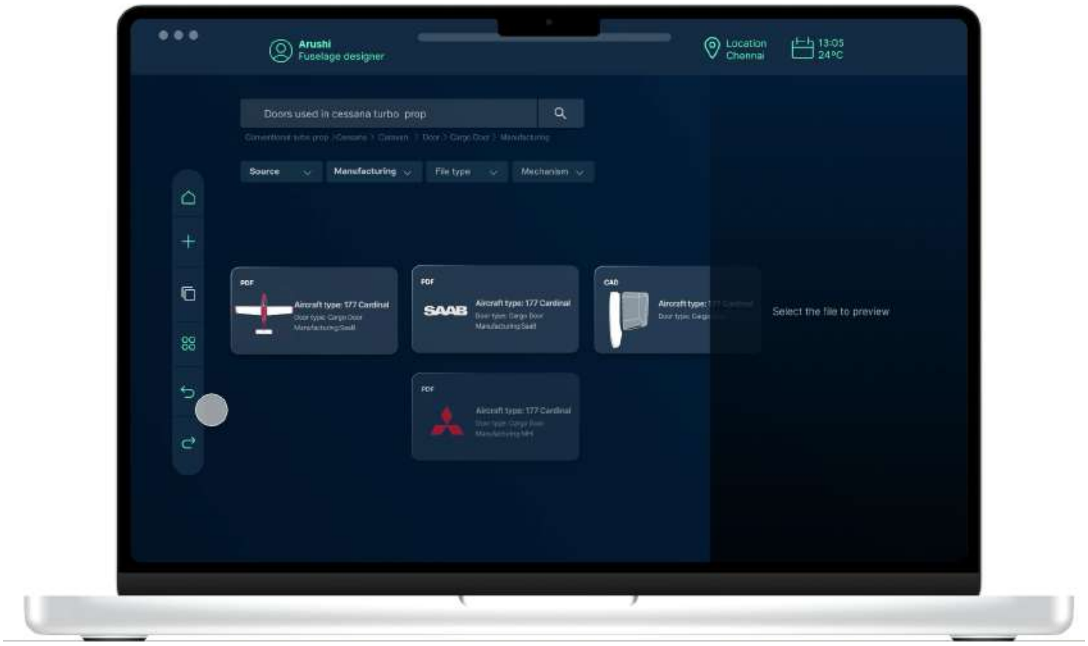


Fig 5.12:Node expansion

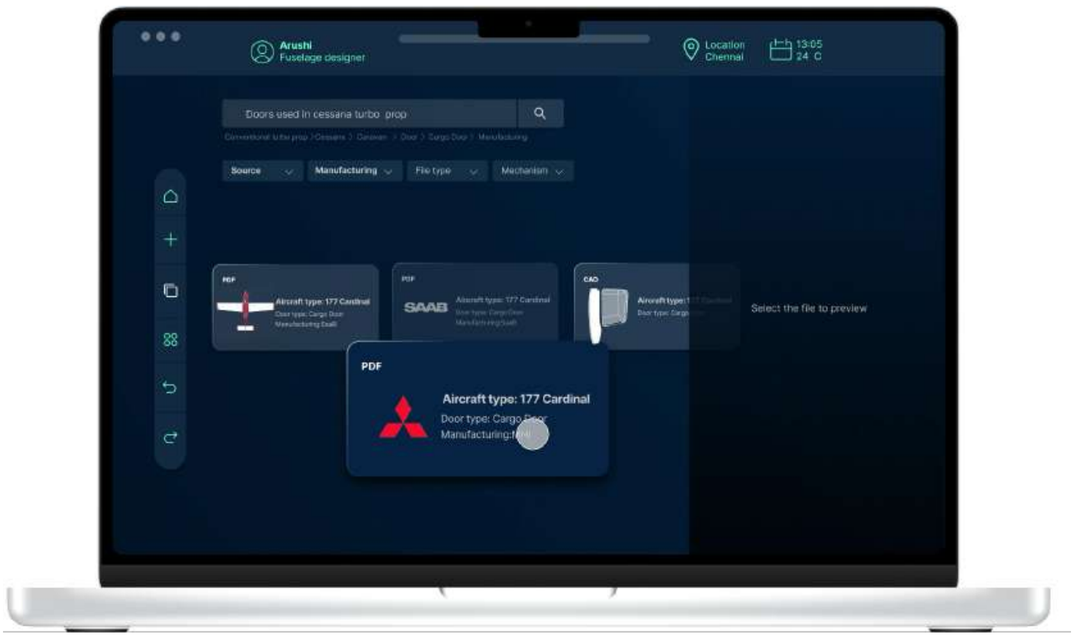


Fig 5.13: When hovering on top of the node

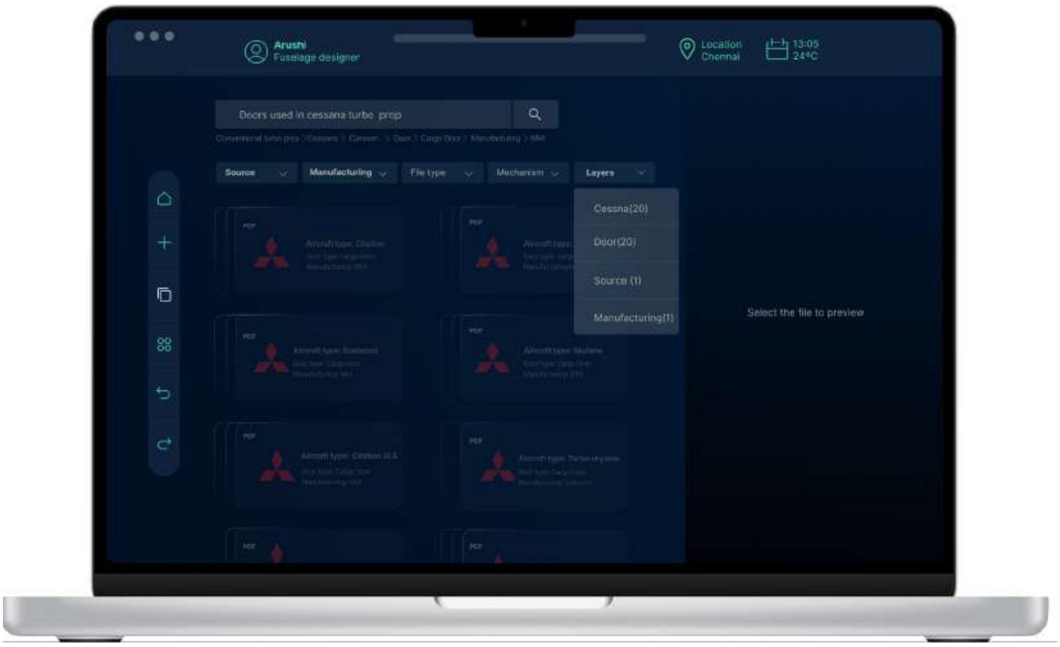


Fig 5.14:Layers navigation

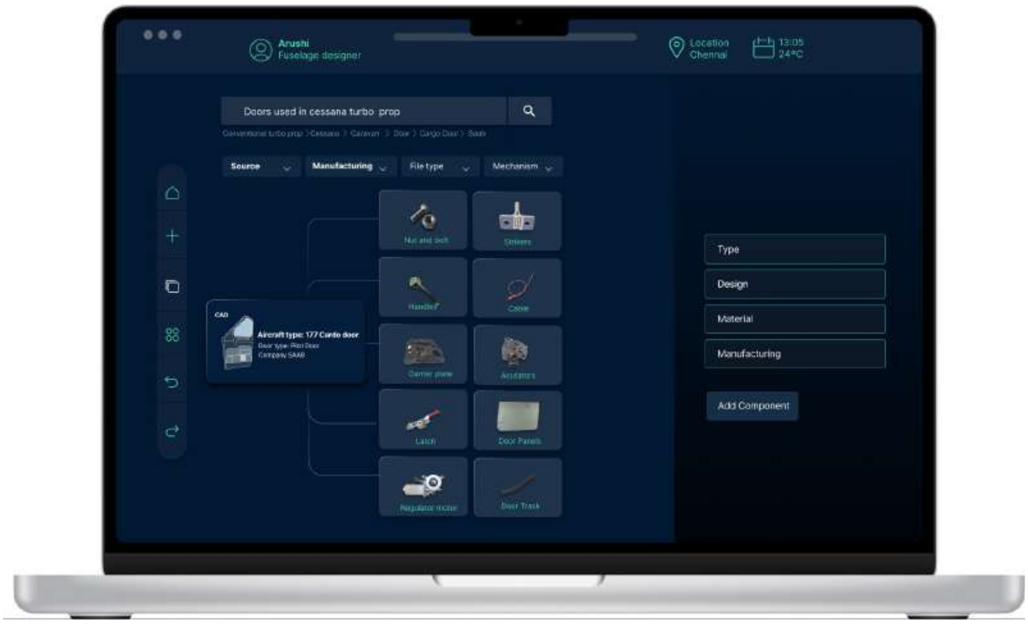


Fig 5.15:Vertical digital thread exploration

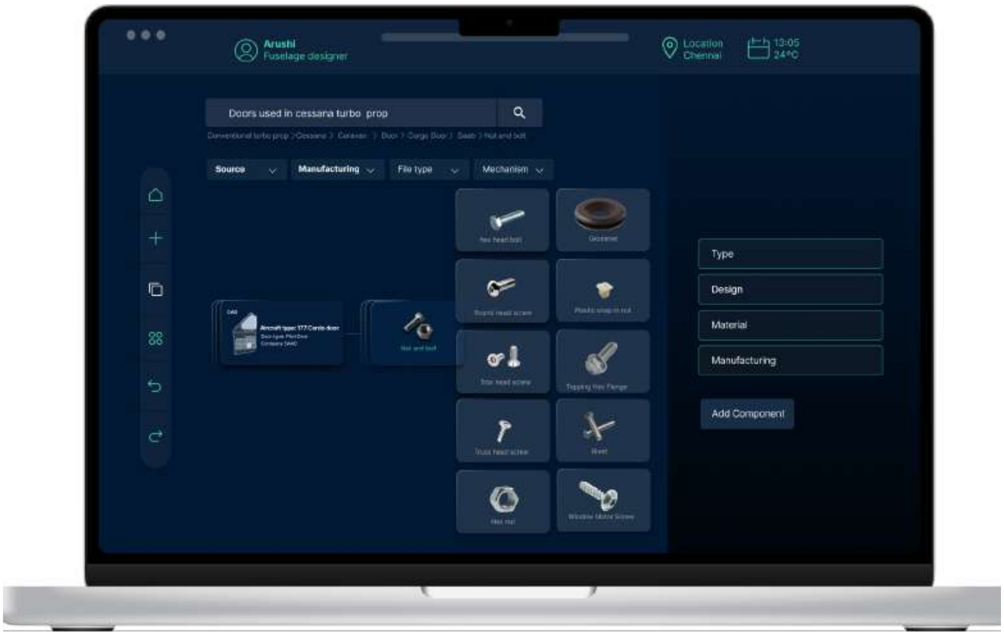


Fig 5.16:Vertical digital thread exploration

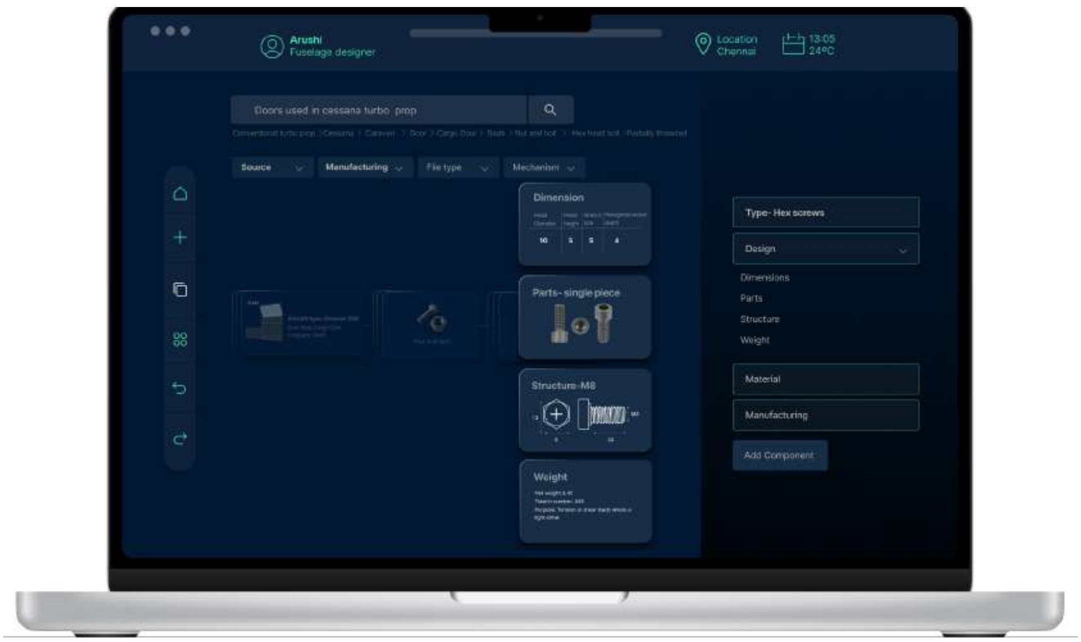


Fig 5.17:Design of the component exploration

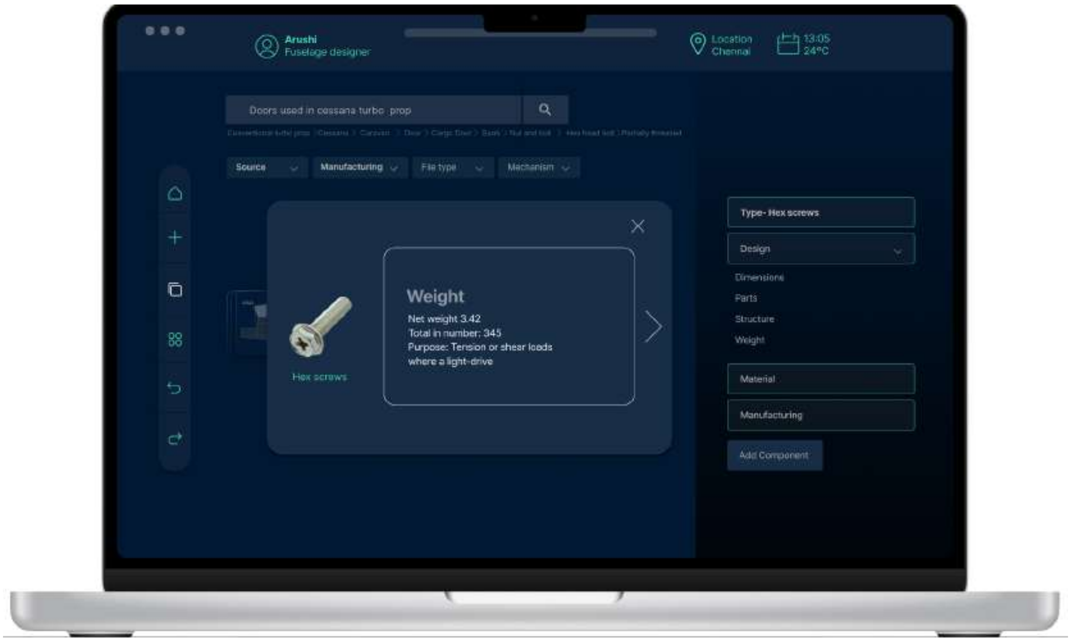


Fig 5.18:Detailed view of the component

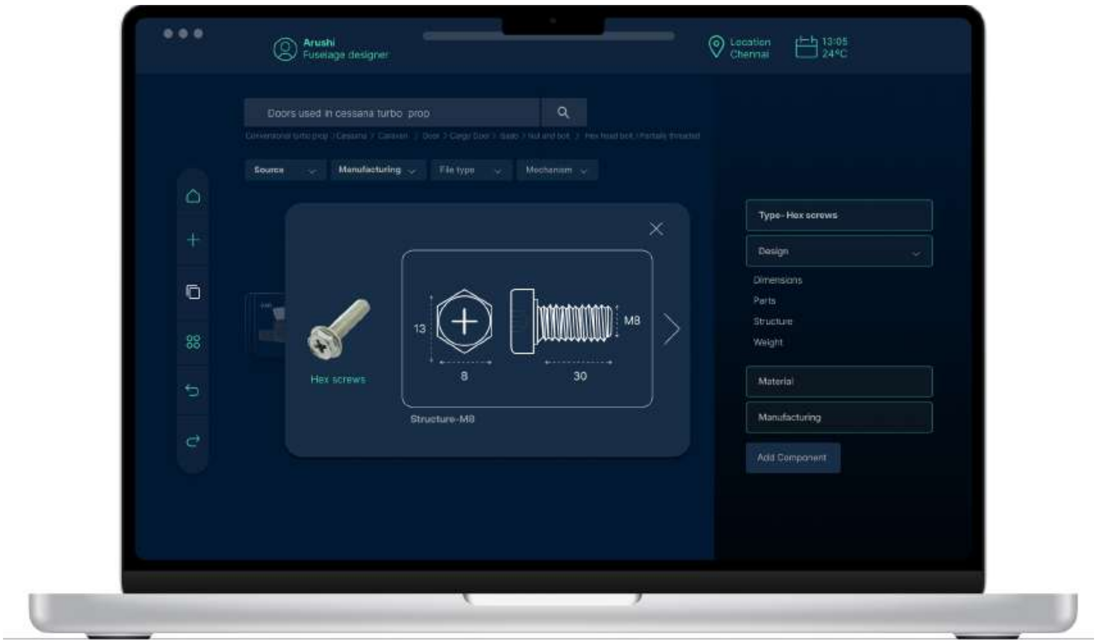


Fig 5.19:Detailed view of the compoent

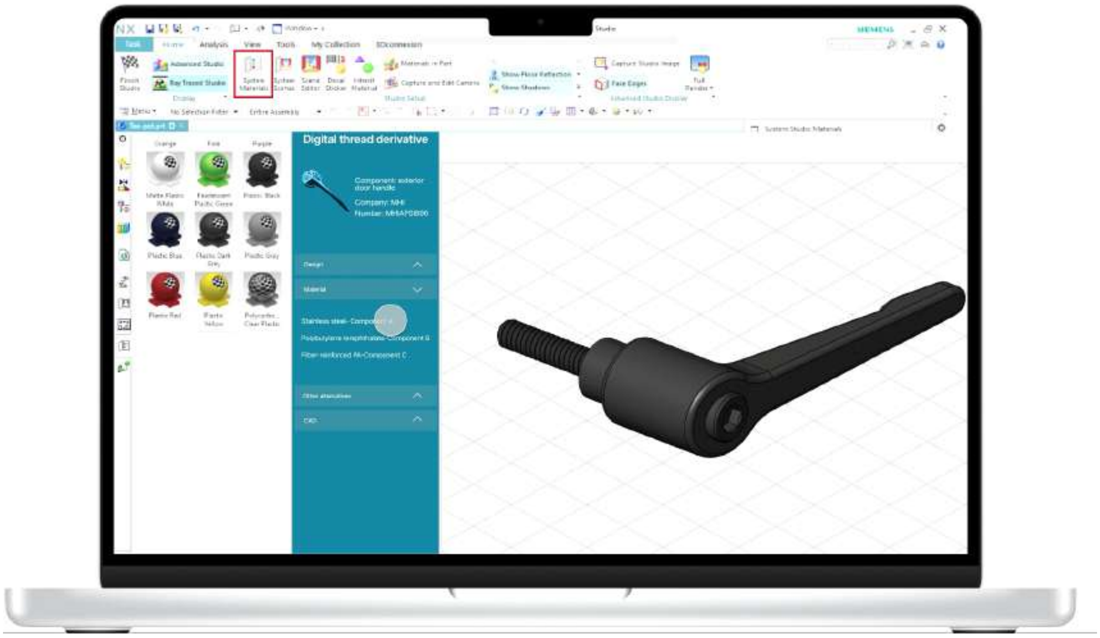


Fig 5.20:Applying design into the NX

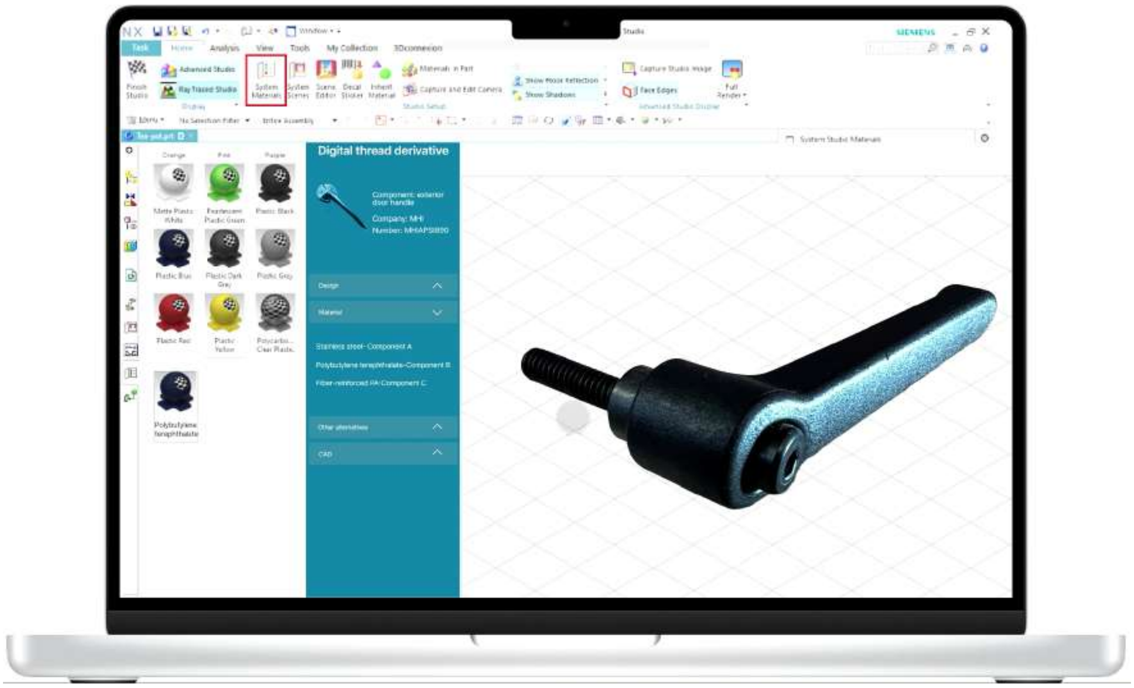


Fig 5.21:Applying design into the NX

Limitations

There are a few limitations to my project. Firstly, this system works in implicit interaction and as the user keeps interacting, the system might keep suggesting, sometimes these suggestions might mislead users as they might be looking for some other information from the digital thread.

Also, the navigation is purely based on the implicit interaction, hence the user has to be very clear while providing the initial search into the system. Secondly, this concept survives in the layering(Grouping of the information according to relevance), while in interaction, the user will have to interact with multiple layers to find out the content he is looking for, this might on other hand lead to loss of time while searching for something very critical. Finally, the time constraint didn't allow for testing and refining the solution. Because of time after designing the solution, the final concept could not be validated for its functioning and understandability for the end users. The solution could be further refined if it had been tested, and the experience of the end users could have been improved.

Conclusion

The digital thread is the future of Industry 4.0. Digital thread is the backbone of the model-based digital twin. The potential of digital thread is enormous and can help in providing information and critical decisions at any time. Many developments are happening in the aircraft industry like hybrid propulsion systems. With these developments and accelerating technologies in aircraft design industry, the role of digital thread and digital could be huge. It takes years of testing and analysis to come up with a single model of aircraft, and with the help of this revolutionary concept, aircraft design process can be accelerated to the next level. Though this project is currently at the concept level and my focus lies on experience, this project has more to look into. The enhanced version of the digital thread (Which will consider other multiple disciplines) will be a very supportive tool for engineers while designing the Aircraft digital twin model.

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Credits

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