# A3AO INTERACTIONS ON LARGE SCREEN

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# Content

# Acknowledgement

It is the time that I finish my master assignment and three years overboard study in Netherlands, my feelings are joy, excitement, remembrance, and enthusiasm for the future.

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Jiacheng Liao
27,08, 2021

# Summary

A3 Architecture Overviews (A3AO) created by Daniel Borches (2010), is a powerful systems engineering development tool that is helpful for effective communications and also a compact toolbox to handle the systems engineering process. Our research aims to develop the A3 Overviews Architecture (A3AO) on large screen devices to cover full usage stages of creating A3AO, reading A3AO and giving feedback for A3AO.

The research begins with stakeholder research which focuses on Asian high tech companies and students. We explore their working process of systems and product development and conclude two kinds of working processes. The stakeholder research indicates the problems in systems and product development and pictures stakeholder traits.

We observe and analyze A3AO functionalities and recognize them as three types: to summarize, to expand and to evaluate. The research proposes that there exists a loop for using A3AO functionalities: summarize, expand, evaluate.

According to three types of functionality category, we use platform design method to decompose the A3AO functionality into main action phases. These main action phases give inspiration for building a platform composed by a series of tools to create the A3AO documents.

Then the research uses systems engineering method in interaction design to build the interaction frame based on results of stakeholder research. The interaction frame covers the full usage stages of creating, reading and giving feedback, and builds the functions and operations inside. At the same time, based on inspiration of A3AO functionality decomposition, a series of create tools are developed to realize the usage stage of creating A3AO documents. Then, the interaction frame guides the visualization. The resulted interaction is called A3AO manipulate center. A demo is developed as HTML interfaces. The demo runs well on A3 sized touch screen tablet and PC.

In the total research process, the research not only results in the interaction of A3AO, but also proposes the using loop of A3AO functionalities and an attempt of introducing systems engineering method into interaction design. Based on total research content, the research proposes statements about understanding systems engineering.

# Introduction

The product development approach in near decades industry faces changes, especially the various new economic forms, new business models, updated technology industries such as chip design and manufacturing, internet services, artificial intelligence, wearable devices, etc. have brought about various requirements for technology development. Inside the current industries mentioned, the multidiscipline cooperation based product development has been more and more common.

The multidisciplinary product development has different requirements compared with single discipline development. The systems engineering approach is introduced to solve the problems and can give qualified solutions in a multidiscipline background development in the last century. In summary, to lead and manage the total multidiscipline based development, the systems engineering is a good developing method that adapts for multidiscipline development's aim and complex systems. However, the previous systems engineering approach was purposed based on last century aerospace industry, it remains a question that whether it is suitable for current blooming new industries or the systems engineering approaches have already been updated in current industries. These changes are good research focus points. At the same time, how to improve the communication inside multidisciplinary cooperation when facing the fast updated industries and business is also a worthy focus point when doing researches for systems development in current industries.

Ten years ago, Daniel Borches (2010) introduces a powerful systems engineering development tool – A3 Architecture Overviews (A3AO), which is helpful for effective communications and also a compact toolbox to handle systems engineering process. And it is evaluated effective by several researchers, systems engineers and actual educational practice of several academic education institutions including University of Twente. Brussel, F. F., & Bonnema, G. M. (2015) try to introduce A3AO to large display devices. However, that research focuses more on potentials and usability predictions but not tries to implement actual concept or design. In our research, the deeper stakeholder research focusing on multidiscipline cooperation in current high tech companies, and comprehensive analysis of A3AO functionalities will be conducted. In this procedure, a streamlined but flexible using loop of A3AO functionalities as well as a new perspective to viewing systems engineering process will be proposed. All these supports the design of A3AO interaction in large screen devices- A3AO manipulate center, which is developed as a demo and runs well in A3 sized touchscreen display device. A series tools are also designed to help the creation of A3AO inside the interaction.

This research itself is an attempt of using A3AO/systems engineering method to conduct interaction design, a procedure is concluded and can give inspirations for the more designers who want to design complex interactions systems.

This research also proposes a hypothesis of systems engineering. It is based on total research content and experiences of investigating, implementing systems engineering, the statements are proposed about systems engineering understating and evolving.

# Research approach

**Research purpose**

1. Exploration of A3AO achieving continuous interaction operation and complete full cycle using experiences in large screens.
2. Further understanding of A3AO.
3. Attempt to use systems engineering approach to do interaction design.

**Research question**

1. How to achieve a continuous, complete interaction frame and logic to get complete presentation and operation of A3AO on large screen devices?

   1.1 How to achieve a general interaction frame, including the components of the layout logic, operation, guide and switch and so on, to cover the full phases of create, review, using and feedback/monitor of A3AO?

**Research approach**

As is shown in the Figure 1, the total research approach begins with stakeholder research, followed one is Analysis of A3AO. Based on stakeholder research and A3AO analysis, we use systems engineering approach to build the interaction frame. Then we do visualization under the guidance of interaction frame, prototype will also be made. After that, we will do discussion and give conclusions.

Part 1: Stakeholder

1. Stakeholders identification of the A3AO interaction in large screens
2. Interviews about working process and problems stakeholders meet
3. Stakeholder analysis

Part 2 Analysis of A3AO

1. Find the similarity between A3AO
2. Build a general logic of using A3AO functionalities
3. Build a general frame of creating A3AO

Part 3: Shape the interaction frame

1. Use the research results of part 1 and part 2
2. Use systems engineering approach to organize functions and operations inside the interaction
3. Build interaction frame

Part 4: Visualization, and prototype

1. Visualization of interaction components under the guidance of interaction frame
2. Design create tools of A3AO based on part 2 results
3. Prototype, it can be developed as a HTML application

Part 5: Suggestions, and discussion

Make discussion and get suggestions for evaluation results, and get conclusion

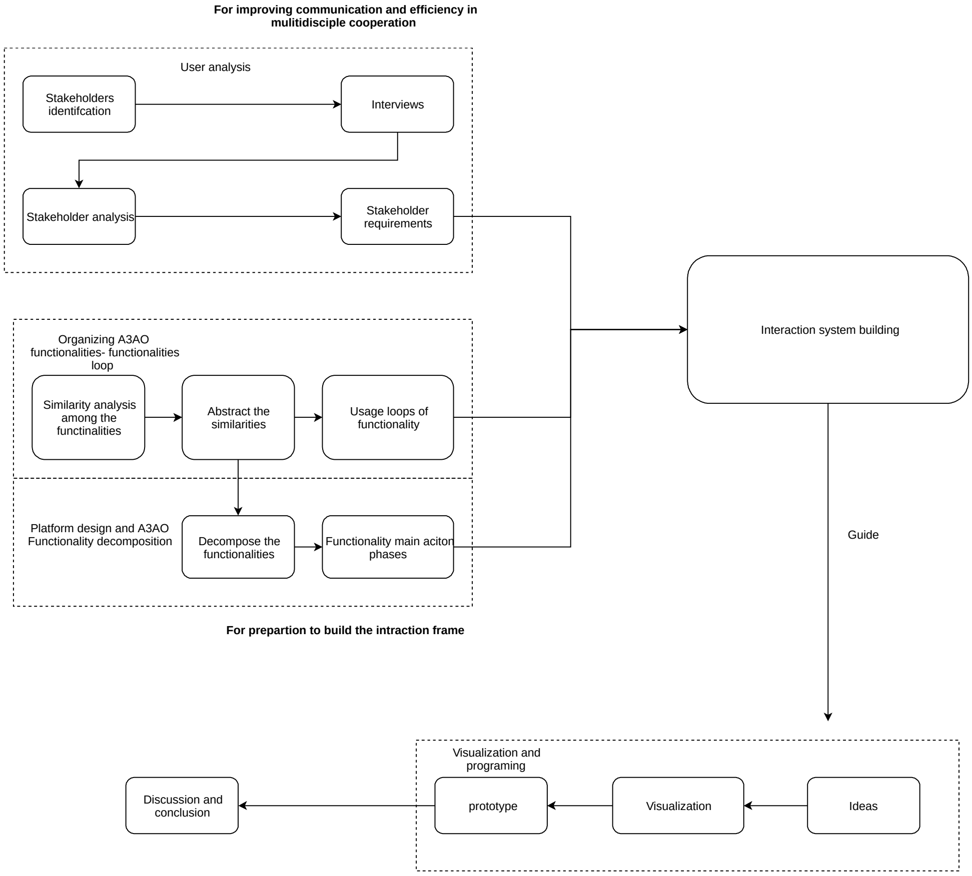



**Figure 1, Research approach**

# 1. Stakeholders

In this chapter, a series of stakeholders' research focuses on systems engineering in product development is conducted by interviewing engineers in Asian background high tech companies and students. The interviews focus on the working process in multidiscipline cooperation and the problems in product development which the participants face, and how they solve these problems, and what are their expectations to improve multidiscipline cooperation. The stakeholder research results in 2 mode of multidiscipline cooperation working process, stakeholder traits, problems in product development and current solutions, and stakeholders' expectations.

## 1.1 Stakeholders' identification

Before the stakeholders' research begin, it is needed to identify who are the stakeholders in research. After that, a series of studies are held to find what are current experiences and ideas about multidisciplinary cooperation and system design.
The system is composed of subsystems. In the practical system engineering process, the systems engineers, subsystem engineers, as well as product managers, project managers, and outside stakeholders work together to design, implement, and evaluate systems in the product development process.

Main roles in system engineering development, what are shows below are basic introductions and definitions of these roles.

- **Systems engineers**

In the traditional definition of system engineers, David D. Walden (2007). Systems engineers（SE）, 'act as the overall system creator. Primarily through stakeholder interaction, requirements analysis, and architectural design, Systems Engineering shapes and influences the system solution through specification, top-down design, and bottom-up integration and test.'

According to Sigal Kordova, 2018, 'A systems engineer is the project's supreme technical arm. Systems engineers must understand the accepted product development processes, "tailor" them to each specific project, implement them in the development process, and pass them on to production.'

- **Subsystem engineers**

Subsystem engineers are engineers who cooperate with systems engineers to implement the systems in the disciplines they are familiar with. Generally, they have professional knowledge and skills. The subsystem engineers widely include multidiscipline engineers, like electrical engineers, mechanical engineers, software engineers, industrial design engineers, and so on. Any engineer that aims to implement part of a system and has his professional ability and experiences can be regarded as subsystem engineers.

- **Product managers**

A lot of companies, that develop products and the systems but do not have systems engineer, they have product managers who play a similar role on managing product development and guide the direction of development. As is mentioned by Horowitz, B., & Weiden, D. (2010), 'good product managers take full responsibility and measure themselves in terms of the success of the product.' According to Paula Gray (2010), product managers 'must be able to envisage the product from start to finish and to have the ability to ensure that this vision and strategy of the organization is realized.'

- **Project manager**

In some companies, the duty of controlling the product development process belongs to the Product manager. 'Project managers are responsible for meeting all project targets, especially providing the product on time and within the determined budget.' according to Sigal Kordova, 2018

- **Outside stakeholders**

In companies that provide products or services to outside business clients but not direct consumers, the business clients also play quite important roles in the development. However, the clients are just part of the outside stakeholders, the cooperated companies, the parent companies are also part of the outside stakeholders. Anyone that is not part of the product system development group but has benefits relationships with the final product can be regarded as outside stakeholders.

## 1.2 Interview preparation

Interview is chosen to be the user research method. Before interviews, a lot of preparations need to be done, it should be made clear that what kind of questions should be focused.

### 1.2.1 Interview method – why choose it

In this research, we decide to use the interview method as the main stakeholder research way. Compared to internet surveys and questionnaires, Interviews can provide more flexibility during the research and more in-depth information from the participants. From others' point of view, as is mentioned by Carter, J. C., Aimé, A. A., & Mills, J. S. (2001), they said interview may have heightened the accuracy of subsequent self-report results when compared to the questionnaires way. Their research about a comparison between interview way and questionnaire way also indicates the interview's benefits.

There is another reason that in this survey, participants must be or will be part of systems developer, it is a comparatively higher requirement to choose proper interviewees. If choosing the questionnaires way, it needs a big number of systems developers. That will be difficult to make preparation. The interview method does not need many participants but can still provide more sufficient information per participant including ideas, insights, suggestions, and so on.

The interviews will sometimes provide a lot of information. The researchers need more time and skills to arrange and abstract information. There is another problem that how to arrange different interviews into a general frame, which will help to generate the final analysis. However, that does not play as the main obstacle when doing interviews. And this problem could be well solved by enough interview preparation and proper way of analysis.

## 1.2.2 Focusing questions

The interview content will vary from person to person, but the focusing areas of the questions should be clarified before the interviews. And these interviews would share a general frame. This frame will have 3 levels, the working process level, the problem and problem-solving in multidiscipline cooperation level and expectation level. The questions inside the levels can be flexible according to the participants' experiences.

The first level focuses on the working backgrounds of the participants and how they get involved in multidiscipline cooperation in their companies. And this part will also focus on what are their companies working process to develop systems or products by multidiscipline cooperation.

The second level focuses on the problems in the development process and how participants solve these problems. The questions will try to find what kind of problems that different roles' developers cooperate with each other. There are four points about problems of cooperation, the problems with project leaders (including systems engineers, product managers, project managers), problems inside the subsystem development group that the participant is in, the problems with other subsystem groups. As is shown in the Figure 1.1, The last point is that, according to G.M.Bonnema (2016), the design process as an iterative loop of alternating analysis (top, in the problem domain) and creation (bottom, in the solution domain), it can be also regarded as the loop of investigating the problem and defining the solution. From this point of view, how the participants deal with the loops in their product development can also be mentioned.

The third level focuses on participants' expectations to improve multidiscipline cooperation in the future. This part will give support to find what they expect and let designers know what kind of design can be effective for the stakeholders.

These levels are combined together as an interview frame and give directions, any questions should be related to them. It still should be noted that different participants vary, the questions should be flexible enough inside the frame.

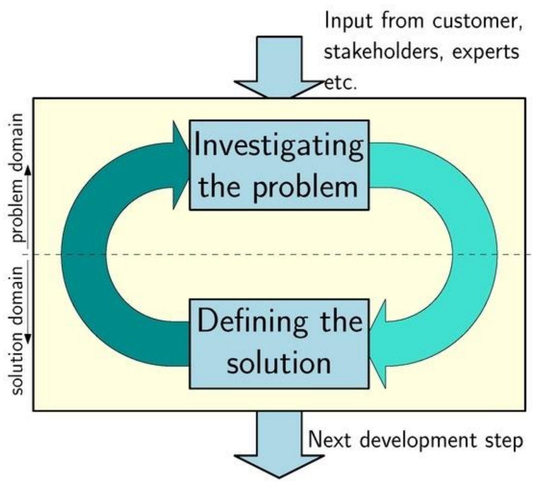



**Figure 1.1, The loop of investigating the problem and defining the solution [Bonnema, G. M.(2016)]**

The Example interview questions (practical interview can be flexible)

| |
|---|
| First, Backgrounds and multidiscipline cooperation working process<br>*'Whether the participant has joined the multidiscipline cooperation in his experiences? And how it works?<br>What the working process is?'*<br><br>Second, Problems and problems solving in multidiscipline cooperation<br>*'Problems with the project leaders<br>Have you worked with systems engineers before?<br>If not, what are the problems of your working experiences with the project leaders/coordinators such as product managers or project managers?<br>Problems with other engineering/design team?*<br><br>*Does the communication run well between different engineering teams?<br>Do your project manager or systems engineers take responsibility of communication?<br>problems in the process of development<br>With the process of project development, when developers are reaching the required goal of the former project plan, will the new problems appear?<br>How you or your team control them?<br>And in the control process, how you communicate with your project manager, get feedback, and negotiate to solve the problem?*<br><br>Third, expectations<br>*'What is your expectation for improving multidiscipline cooperation?'* |

## 1.3 Interview

### 1.3.1 Interview introduction

The interviews were from December 2020 to February 2021, 7 participants were involved. 3 interviewees are students, the other 4 are all experienced engineers from Asian high tech companies. Because of the high speed of modern industrialization and economic blooming, many new business models and technical advances are taking place in Asian, the Asian high tech companies (especially China) deserve to be pay more attention.
All the areas about working process, multidiscipline cooperation's problems and problems solving, expectations are covered in the interviews. The time range from 40 minutes to 1 hour. The interviews were held online, by videos or audios. All participants have approved audio recording during the interviews.
The languages used in the interviews are Chinese and English, all the audios are transferred to text documents. All text content is translated to English.

## 1.3.2 Industry Backgrounds

The interviews focus on the high tech Asian companies and industries. These companies are set in east Asia (especially China) and face the world market. These companies focus on chip design, internet services, electronic hardware design, customer devices industries. They grow at a very fast speed. Some of them are top 500 companies in the world (HUAWEI) or occupy the leading position in their domains (TIKTOK).

It is because they are representative, successful in products, guiding the industries, and growing rapidly that they are chosen to be part of the interviews. There are also important reasons about technology that their products have to some extent complexities, and these companies think highly of systems and architecture thinking. All these reasons make them have enough value to be interviewed and researched.

**Table 1.1, The basic information that related to the interviews.**

| Company name involved | Industry and main business area | History | Famous products/services | Business location | Research and innovation |
|---|---|---|---|---|---|
| Huawei Technologies Co., Ltd. | Huawei is a leading global provider of information and communications technology (ICT) infrastructure and smart devices.<br>For carrier:<br>- wireless network devices<br>- fixed network devices<br>- cloud core network<br>- service and software<br>- digital power<br>- autonomous driving network<br>For customers:<br>- smart phone<br>- laptop<br>- pad<br>- television<br>- VR<br>- wearable devices<br>- audio devices<br>- routers | Founded in 1987, Rank 49 in Top 500 companies by Fortune 2020 | LTE base station, 5G base station, Smartphones, Autonomous driving network | Head office: Shenzhen, China<br><br>Business location: Asia, Europe, Mideast, Africa, South America | More than 100000 patents; 590+ journal and conference papers in high-impact channels; More than 720 billion CNY ( 92 billion EU) research investment in last decade. |
| Beijing Bytedance Network Technology Co., Ltd. | Bytedance is a global internet products and services provider to inspire creativity, enrich life.<br>Product line:<br>- Douyin (Tiktok name in | Founded in 2012, Douyin Launch | Tiktok | Head office: Beijing, China | Be famous of Personalized information push service technology |

| | | | | | |
|---|---|---|---|---|---|
| | China)<br>- Tiktok (Short video platform in the overseas market)<br>- Toutiao (most popular content discovery platforms in China)<br>- Xigua videos ( one of China's most popular video applications )<br>- Lark ( available in Japan and Singapore, combines a multitude of essential collaboration tools to do work management) | ed in 2016, Tiktok lunched in 2017 | | Business location: 150 markets in Asia, Europe, America, Africa | based on data analysis; |
| Cambricon Technologies Corporation Limited | NPU design:<br>- Smart Accelerator Card<br>- Smart Acceleration System<br>- Edge Computing Module (AI acceleration)<br>- Terminal Intelligence Processor IP | Founded 2016, IPO in 2020, | Siyuan 290 | Head office: Beijing, China Business location: China | Be famous of NPU design; 245 new patents last year |
| Shenzhen Xinyin Technology Co., Ltd. | TWS earphone design, ODM, They are an intelligent manufacturing enterprise engaged in the design and development of intelligent products such as TWS headphones, speakers, home appliances and so on. To build a high-tech industrial park with smart speakers, headphones, home furnishing and home appliances as the main products, integrating research and development, production and sales. | 2020, Purchased by Sunwoda Electronic Co.,Ltd. (Battery manufacturer) | TWS earphone for smart phone manufacturer | Head office: Shenzhen, China<br><br>Business location: Asia, | Specialized in integrated TWS earphone design |

Figure 1.2, The logo of companies involved

### 1.3.3 Participant's introduction

There are 7 participants that participate the interviews. 3 of them are students, 4 of them are experienced engineers in Asian high tech development companies.

The diagram below shows the basic information of the student participants, one is from the Beijing Institute of Technology, the other two come from the University of Twente.

Table 1.2, Basic information of student participants

| Participant No | Name | Position | University | Work experience |
|---|---|---|---|---|
| 1 | CY | Chassis system engineer | Beijing Institute of Technology | No working experiences |
| 4 | Nick | Industrial designer (composite track) | University of Twente | Internship |
| 5 | HY | Mechanical engineer | University of Twente | Internship |

The diagram below shows the basic information of the experienced participants. That includes their participants' age number, position in companies, the companies and industries they worked for, their ages, and working years.

Table 1.3, Basic information of experienced participants

| Participant No | Position | Company and industry | Age | Working years | Note |
|---|---|---|---|---|---|
| 2 | Algorithm | Cambricon | 24 | 1 | |

| | | | | | |
|---|---|---|---|---|---|
| | engineer | (AI chip design) | | | |
| **3** | Industrial designer | Xinyin (TWS earphone design) | 26 | 3 | Design leader now |
| **6** | IC systems engineer | Huawei, ZTE (chip design) | 35 | 10 | Work as subsystem engineer before, now a SE |
| **7** | Product manager | Tiktok (Internet services) | 25 | 5 | Successful in Tiktok |

### 1.3.4 Interview summary

**Interview 1**

The interview 1 focuses on CY, a master student in the Beijing institute of Technology in China, his major specification is chassis of vehicle system design. The interview lasts 30 minutes.

He is familiar with the system optimization process, although he does not have practical working experience. From his point, this kind of multidiscipline cooperation needs an in-depth understanding of different disciplines.

From his understanding of implement parameter optimizations, he used to divide the problems into system level and subsystem level, and different disciplines work in parallel. The paralleled running disciplines can enhance improve computational efficiency greatly. At the same time, the results will be fed back to system level, and the system level will make decisions. He uses isight software to do the optimization process. 'Isight and the SIMULIA Execution Engine are used to combine multiple cross-disciplinary models and applications together in a simulation process flow, automate their execution across distributed compute resources, explore the resulting design space, and identify the optimal design parameters subject to required constraints.' Dassault (2021) And he also uses this software to deal with the looping problems in system optimizations.

He gives his expectations about the subsystem engineers should clearly know the design goal and the model needed. And he also mentions that the communication interfaces should be clear.

**Interview 2**

The participant 2 is JW, working as the Algorithm engineer in an NPU design company in Beijing, China. This interview takes 40 minutes.

In this interview, he clearly shows how the company works in a multidiscipline way. He also clarifies the System architect role in his company. And the system architect is similar to systems engineers in definitions. The detailed working process will be introduced in the next part. It is interesting to point that, in his company, the architect engineers works as a team to

reduce errors and enhance system quality. Another point is the technical document plays a very important role in their systems development.
The problems he meets is the often changing requirements from outside stakeholders, and he also mentions that the system's maturity, compatibility, robustness are quite important. For the question of how to deal with too many loops of investigate problems and give solutions, he said that too many loops will not happen because of the group decisions.
He gives his expectations about to increase awareness for different discipline knowledge by training from the companies.

**Interview 3**

The participant 3 is L, he works as an industrial design leader in a TWS (true wireless stereo) earphone design company in Shenzhen, China. The interview takes 30 minutes.
The development group in his company involves different background engineers, the working process will be shown in the next chapter. There are no systems engineers in his team, but the product manager and project manager play similar important roles. He clearly shows how the product manager transfers outside stakeholders' requirements to technical requirements, such as battery length, audio quality and so on.
The main problem he meets is the subsystems sometimes contradict each other in development. His development group uses meetings to solve the problems, and each meeting will involve related engineers to discuss how to solve problems. He also mentions that the product manager will give higher design requirements then compromise step by step to ensure the final product quality, and the product definitions are quite important. For the questions of looping problems, he mentions that the product manager will lower down the requirements to compromise.
He also mentions there are specification documents in development. And it is the work of the product manager. The outside stakeholders play quite important roles, and they have rights of making decisions on this specification document. Sometimes, the stakeholders' needs of the products change, and the specification documents must be modified as well.
His expectation about multidiscipline cooperation is that the face to face communications could be better.

**Interview 4**

The participant 4 is Nick, a master student of the University of Twente, major in industrial design engineering, track in emerging technology design and specialized in composite design. He has 2 internships in the Netherlands and now works for a company to finish his master assignment. The interview nearly takes 40 minutes
In his working experiences, he has a different discipline background leader, and he faces language problems in communication. On the other hand, he also faces different discipline works. Sometimes he faces problems with that, and he will pretend to say ok, but in fact, he does not really solve them.
He has a lot of expectations on improving multidiscipline cooperation. Such as solve the problems of jargons in different disciplines, change the display preferences (graphic or data), improving visualization and parameter combinations, easy to comment, use more tools to work with models and so on.

**Interview 5**

The participant 5 is JY, a master student of University of Twente, major in mechanical engineering, has 2 internships in the Netherlands. The interview takes 1 hour.

In the companies, he directly contacts his leader. And he faces a lot of multidiscipline works. He clearly introduced how he handles this work. The working process begins with being familiar with the new object, then he combines core ability in his own discipline, after that, he makes use of universal analysis ability: data analysis and processing capabilities, finally, using experimental data for further verification.

He has expectations like there could be a bridge role in the development to connect different departments and disciplines in multidiscipline cooperation.

**Interview 6**

The participant 6 is Yuan, an IC systems engineer in China. He has working experience of chip design in several high tech Asian companies, such as Huawei, ZTE, and so on. The interview takes 1 hour and provides a lot of useful information.

He firstly introduces how multidiscipline works in IC chip design, the working process is clearly shown in the next chapter. He clearly describes how the systems engineers clarify what to do, then transfers to the tasks, and then assign it to different people, finally integrate all the responsible engineers' works. He also stresses the importance of the evaluation engineers, the design and verification time ratio is 3:7. The relationships of Front end IC engineers and Back end engineers are also clearly shown.

He mentions problems in systems design. He indicates that it is better to directly solve the problems but not to generate too complicated solutions by too many times iteration. He also stresses the importance of interfaces in system design. And when designing the systems, it is necessary to write clearly what interface should be created or managed.

The technical documents are also well used in his companies, the system engineers and subsystem engineers push the work by technical documents, such as overall design plan, basic plan document and detailed design plan.

For the looping problems, he says it is the duty of the verification engineers, they can indicate where the problems are. They use a bottom-up way to do evaluations.

He shares his feelings about developing systems in big companies and small companies. And he says that the industry uses Top-down design most of the time.

He indicates problems in his teams 'communications. One of them is the subsystem engineers could not understand the requirements clearly, which could lead to too many iterations. Another problem is between higher leaders and SE, subsystem engineers, that is about the progress control. The leaders always want to push the progress and the time given for engineers are not engough. It can also be regarded as a problem of engineers' technical abilities.

Finally, he gives his expectations in multidiscipline cooperation about quick feedback when facing problems and the group should have active communications.

**Interview 7**

Participant 7 is Hao Y, working as a product manager in Internet services companies in Beijing, China. One of his most outstanding working experiences is working as product manager of Tiktok in Bytedance, a worldwide famous video internet product. The interview takes about 40 minutes.

He introduces the working process of internet services/products. It is organized by several meetings, the purpose meeting, the plan meeting, the requirements meeting, and the summary meetings. The leaders (outside stakeholders), product managers, technical engineers, designers are involved in this process. The details of this working process will be introduced in the next part.

He also introduces the problems in multidiscipline cooperation. He talks about the problems of communicating with leaders, which can happen in each step but these problems will decrease with the progress of development. He also says his solutions to work with leaders-to bridge the information gap and increase agreements.

Then he says about problems with other product managers. Those are not about the cognition problems in professional areas, but about the profits/interest distributions. In this part, the rewarding regulations in companies are important.

After that, he introduces the problems of cooperation with design and engineering teams. He stresses the importance of direct communication. There are two reasons to do that, the first is that it is a process of giving himself pressure, the second is that the requirements plan can have high quality, and the engineering team will have expected benefits to working with him. When dealing with the requirements levels problems, some requirements will be remarked as 'S' level. Some consideration should be noted when remarking. So, not all requirements will be processed as the 'S' level (highest) level, which require to communicate with the development part. The development difficulties and expected benefits should be comprehensively considered. There are also problems to work with engineers. Sometimes, the engineers do not understand the requirements, and sometimes there will exist some delay in procedure and the subsystems engineers give low quality solutions. He solves these problems by being familiar with the knowledge, having the ability to judge the problems, having the ability to cooperate to solve problems in engineering, can give suggestions. To conclude of his solutions to solving problems with the design and engineering team is to bridge the gap of disciplines backgrounds, and to keep a self-learning attitude. At last, he also stresses the importance of keeping trust between product managers and the design and engineering team.

He introduces how he solves the problems which often appear in the product development process. That is to check step by step and in a bottom-up way.

Finally, he gives his expectation for multidiscipline cooperation: Everyone has agreements in cognition fully, and be effective on executions, and the work can be fast and efficient. And he also gives his suggestions: The purpose is aligned, and the information is symmetrical. The execution efficiency is related to trust inside the development team. Product managers should know the work of design, technology development, marketing and so on. And the product manager can make judgments on quality.

# 1.4 Interview analysis

In order to deeply get meaningful information, more interview analysis is conducted. The interview analysis part focuses on the working process, stakeholders' traits, problems in multidiscipline development, the solutions from participants for problems and the expectation summary. All these analysis base on the interview recordings and those audio recordings are processed to texts when doing analysis.

## 1.4.1 Working process

The first part is the working process. For the experienced participants, how their companies do multidiscipline cooperation product development, and what are the details in this process, and what kind of stakeholders are involved in the process, what kind of key factors drive the product development. All these questions will be explored in this working process part.
The working experienced participants provide their working process

### 1.4.1.1 The working process from interviews

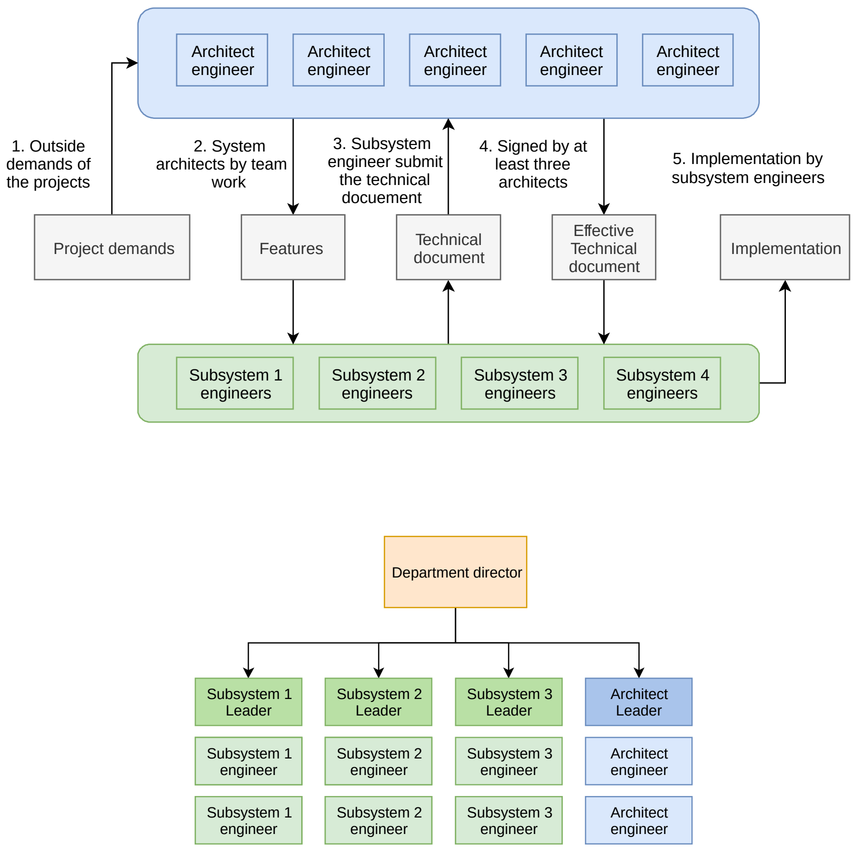



**Figure 1.3, Working process 1**

**Introduction 1**

It is the working process of participant 2's company, the major work of his company is to design NPU chip.

Generally, architects disassemble the features, then transfer features to functions, and distribute the functions development to different engineers. But subsystem engineer does not start to do it right away, they must think about which kind of code our department is going to use to implement the function. The architect will only give the functions but not tell you how to write the code, and subsystem engineer get the function that you are going to implement as your task to do.

At the beginning, subsystem engineers must write a technical document about how and which kind of code are you going to use to implement the function. In this company, the subsystem engineers must submit this technical document as soon as it is written. If the leader and the system architects think it is ok, they will respond back, and subsystems engineer can start writing code.

For the technical document. The company needs at least 3 architects to approve it. When the subsystem engineer submits a technical document, every architect can review it, if they feel that there is no problem, they just will approve it. If three architects like it, it means the technical document is approved. In this kind of regulations, three system architects can always guarantee the quality.

After the technical document is approved, the subsystem engineer can begin his implementation work. The process is shown in the Figure 1.3.

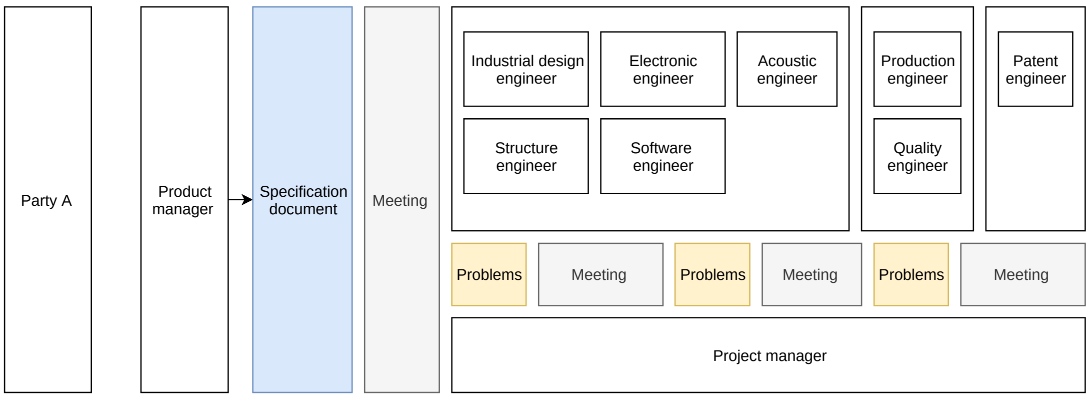



**Figure 1.4, Working process 2**

**Introduction 2**

This diagram describes how participant 3 company works. Firstly, the Party A (outside stakeholders) gives his requirements. Then the product manager in our company will get the requirement and begin to work. The product manager will do a specification document, it clearly writes the specification and requirement of the product.

After that, the development process is driven by several meetings. If the development team has some problems, such as the subsystems have conflicts with each other, the project manager will invite related engineers to have a meeting to discuss and make decisions together. If they still can not decide, they will invite the development director to join the discussion and make decisions. This kind of meeting will be constantly held until the final product is developed. The process is shown in the Figure 1.4.

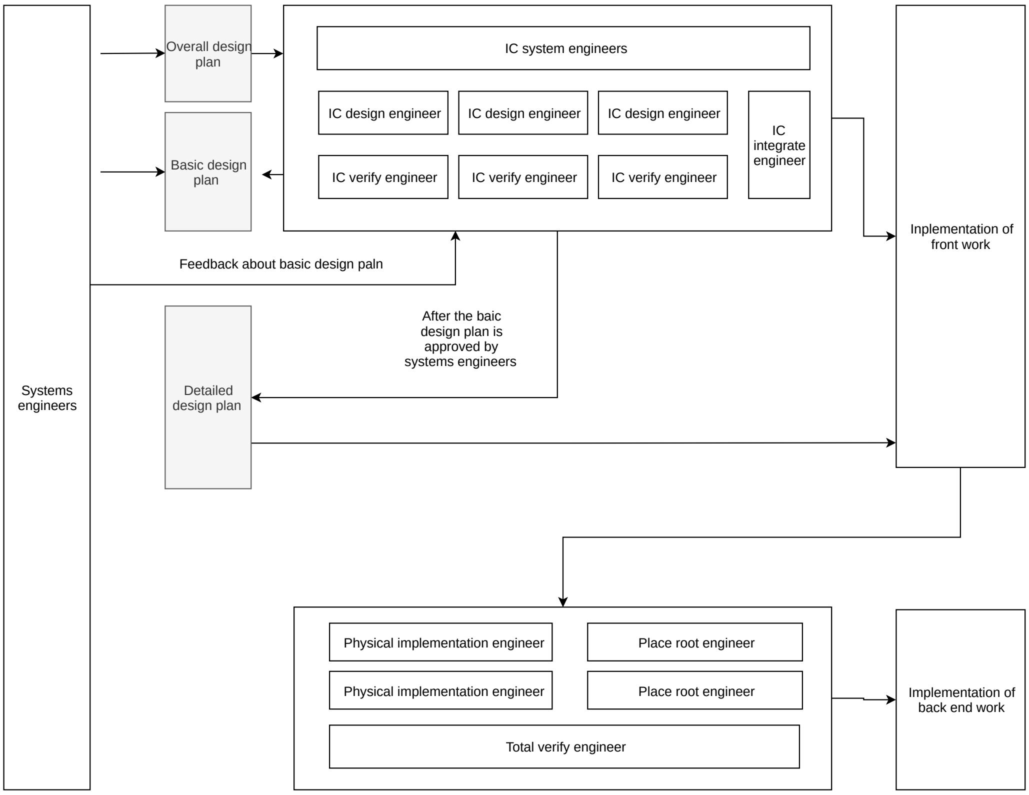



**Figure 1.5, Working process 3**

**Introduction 3**

This diagram introduces the working process of IC chip design companies from participant 6. In this process, the systems engineers play important roles.

There are a lot of different engineers cooperating, including front-end IC engineers and back-end engineers. The front-end IC engineers include design engineers and verification engineers, and IC integration engineers. The back-end engineers include Physical implementation engineers, Place root engineers (to place the circuit according to the module), and Total verify engineers.

Firstly, the SEs get the requirements, they must analyze whether the requirements can be achieved. If they can be achieved, SEs must split them. And they will conclude it as the overall design plan. After the overall design plan is handed over, the IC engineer does not write the code quickly, they should think about how to achieve the functions. They will write the basic plan document, the basic plan document will not be so detailed, and then SEs will do a plan review to see whether the plan can work at a general level. After passing the review, the IC engineers will write a detailed design plan. The detailed design plan will guide the implementation of IC front design work.

In front-end IC design, there are design engineers and verify engineers. The work of IC design needs a lot of coding. The distributed work of design and verification of the IC front-end can ensure the code quality, and the design and verification time ratio is 3:7. It should be emphasized that verification engineers need to consider a lot of technical corners, and many different scenarios. During the verification process, the design engineer will also participate in verification work. In fact, the verify engineer is not as familiar with the practice of using scenarios as the design engineer. When the design engineer considers a specification, the verification engineer should also consider it, but if the design engineer leads the verification, he will have preconceived ideas. Therefore, the verification engineer has his own set of processes. The two of them are completely parallel processes, one is writing design and the other is writing verification scheme. After the design engineer finishes his work, he will give the verification engineer his work to verify the plan, and the verification engineer will give feedback to the design engineer. If there are problems according to verification, the verify engineer think the design are unreasonable and need to be discussed, the verify engineers must persuade design engineers to modify. If verify engineer think the design are reasonable, the verification engineers must know why something goes wrong, and they must convince the design to modify it. These two people are in an iterative process, an interactive process. The front-end design and verification can at least shape the functions, now that the design and verification of the chip are done, the IC integration engineers will combine previous work together, but it still stays at the code level.

When it comes to the back-end, the first thing to do is to synthesize the function. He will translate the code into a NAND gate. These are all done through tools (digital design Synopsys, analog design Cadence.) After translation, because the chip is actually just a wafer, and wafer will continuously be cut, and the chip is connected by wires. The influence of static electricity should be considered. If the wires are too close, there will be interference between electrons and electrons. So, the back end design should not be done blindly, the hardware engineer including physical implementation engineers, and PR engineers (place root), will place the circuit according to the module. They often must consider avoiding long wiring to improve structural efficiency. After they are done, they will form a grid-like table, And then this will be given to chip manufacturers TSMC and SMIC. The design phase is finished. The process is shown in the Figure 1.5.

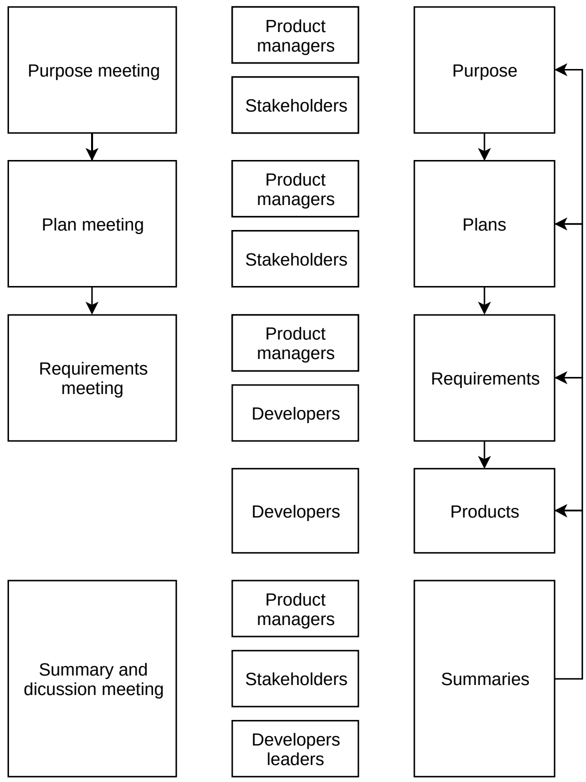



**Figure 1.6, Working process 4**

### Introduction 4

This diagram shows the working process of participants 7's company. It is an internet company working method. It is pushed by several meetings.

Meeting 1: Purpose meeting

The product managers and the leaders(boss) will get together to discuss the next version of the product, and what kind of problems are going to be solved. The requirements and products plan will not be discussed at this time. What to do in this meeting is according to the current situation to define the purpose.

Meeting 2: Plan meeting

Based on the purpose, we give some product plans. These plans are not complete documents, but some summary prototypes and documents that can express your product plans. Everyone can look at that and make judgments that whether it can solve previous problems.

Meeting 3: Requirements meeting

The third meeting is about the product manager prepare the requirements documents, then explain them to development groups. The detail development plan will be surveyed by their groups and we will not participate in that.

There is a final meeting to summary after all development, and all stakeholders will be evolved. And in this meeting, there will be a bottom-up evaluation phase, and evaluate the product of the developed version, and find whether there are any problems and find where the problems are located in the product development, the software/technology level, or requirement level, or plans level or higher level. The progress is shown in the Figure 1.6.

1.4.1.2 Findings of working process analysis

There are two kinds of working process from the participants interviews. The first one is flexible meeting driven working, the second one is precise document driven working.

Working process:

**1. Flexible meeting driven**

The flexible meeting driven working process means that the engineers do not need to build the system in detail, but to push the product development by several meetings.

Working process frame:

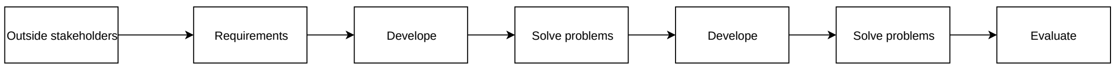



**Figure 1.7, Working process frame 1**

Scope: middle or small companies, and no high requirements on complex technologies.

Description： This kind of working process is quite flexible, and it is summarized from participant 3 and participant 7 descriptions. It pushes the product development by a series of meetings, the meetings can follow a general frame (from participant 7 interview) and can also be arranged by practical problems (from participant 3 interview). There exists a loop of developing and solving problems What is common in this working process is that the meeting has obvious effect to advance the product development and the meetings sometimes have significant meanings for the progress.

**2. Precise documents driven**

The precise documents driven means that using technical documents to drive the product development strictly and precisely.

Working process:

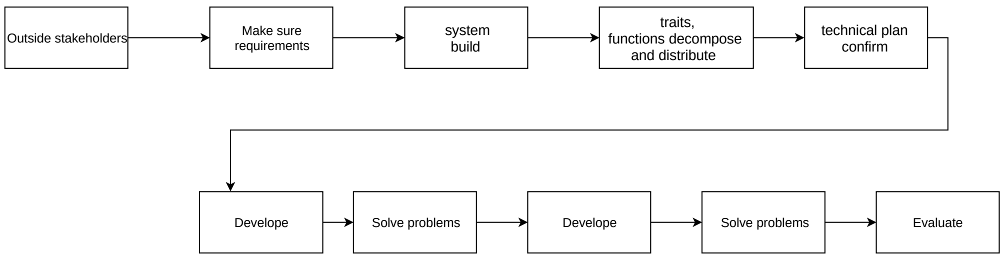



**Figure 1.8, Working process frame 2**

Scope: big companies, has high requirements on complex system and technologies

It meets the disciplines of summarize, expand, and evaluate in the next chapter.

Description: This kind of working process most significant character is that the technical related document plays a strong role in product development. This process is summarized from participant 2 and participant 6 interviews. This process requires system building, and in each phase, the technical document will drive the development. Some subsystem technical document also requires approvement from systems engineers/ architects. The technical documents are the key for all development phases and directly push the progress. And there exist a loop of developing solving problems. The document driven working process is more complex, but also becomes more precise and adaptable for high tech product development.

These two kinds of working processes are not fixed, but the one will play the major role. Meeting driven companies need technical documentation to support the progress. Documents-driven companies also need some meetings. Whereas meeting-driven companies rely on meetings to drive project development, document-driven companies rely on specific technical documents to drive project development.

### 1.4.2 Stakeholder traits

After analyzing the working process of the participants and the full recordings of the interview content, the traits of typical stakeholders in multidiscipline development are got. The traits of stakeholders will help us to do later analysis about solving problems in product development and get preparation for the design.

**Subsystem engineer**

*1. Be responsible for his own technical/development plan.*

*2. Need to communicate with the technical supervisor or SE, and the technical plan should be approved by the technical supervisor/SE (in documents driven companies).*

*Need to communicate with product manager to get the requirements, and finish technical plan by himself (in meeting driven companies).*

*3. Act as executer more than decision maker.*

*4. The understanding of requirements is directly related to the working effectivity.*

*5. Sometimes need to participate in multidiscipline meetings.*

We get the subsystem engineer traits from participants 2,3,6,7 directly working experiences, and from participant 4,5 internship experiences. The 5 main traits clearly show what kind of role the subsystem engineer plays in high tech companies.

The subsystem engineer is a definition that the engineers focusing on certain domain comparatively with systems engineer. For point 1, They are the main implementation operators in development and their role is more related to their own disciplines, and they need to develop and responsible for their own technical plans.

**Systems engineer**

*1. Need to effectively summarize the stakeholders' requirements and transfer them to systems functions and characters.*

*2. Deep understanding of different disciplines' knowledge.*

*3. Need to make the overall plan, reduce re-bridging (bridge the gap of different subsystems too many times), and repetitive work, optimize the efficiency of the structure.*

*4. Need to do the technical evaluation for subsystem engineers' plans.*
*5. Design the system in a top-down way.*
*6. Check problems in a bottom-top way.*
*7. Can work as the single SE, but also can work as a member of the SE team to do the group decisions.*
*And sometimes group decisions can avoid errors and improve plan quality.*
*8. Attach importance to systems structures.*
*9. Grow up from a subsystem engineer and has several years working experience.*
*10. SE needs to review the compatibility of the interface.*

We get the system engineer traits from participant 2 and participant 6 interviews, especially the participant 6, he now works as an IC SE and has some deep insights for system engineers. There are 10 traits that are concluded according to the interviews. Some of the traits are also related to the previous literature, some traits like No 6,9 are generally acknowledged. The trait No 7. The group decisioning to improve plan quality are new findings that can not be found in the literature.

These points about systems engineers' traits are also mentioned by some researchers. For point 1, Sheard (1996) indicates that the first role of the systems engineers is Requirements Owner (RO) Role. 'Requirements Owner / requirements manager, allocater, and maintainer / specifications writer or owner / developer of functional architecture / developer of system and subsystem requirements from customer needs.' Frank, M (2006) indicates that 'Successful systems engineers are able to perform requirement analysis including: capturing source requirements, defining and formulating requirements, generating System Requirements Documents (SRD), translating the concept of operations and the requirements into technical terms and preparing system specifications, validating the requirements, and tracing the requirements.' For point 2, Sheard (1996) says that systems engineers also play a Glue (G) Role. 'Owner of "Glue" among subsystems / system integrator / owner of internal interfaces / seeker of issues that fall "in the cracks" / risk identifier / "technical conscience of the program"' For point 3, Frank, M. (2006) indicates that systems engineers should understand the whole system and see big picture. But he does not mention the requirements of reducing re-bridging and repetitive work, which is emphasized several times by participants and important in real practices. For the point 4, Fran, M (2006) also mentions that the successful systems engineers need to validate the requirements. Walden, D. D. (2007) shows the COTS-Based SE Vee process figure, which indicates the relationship between requirements and the verification. For the point 5 and point 6, Walden, D. D. (2007), says in Traditional Systems Engineering (TSE), the systems engineers are creators and that is a top-down definition and bottoms-up integration and test approach. For the point 7, it is currently not mentioned in the references, but the participants emphasized several times in the interviews, group decisioning between systems engineers are used to decreases the mistakes. For the point 8, and point 9, there are no references strongly related to that, but Davidz, H. L., D. J. Nightingale and D. H. Rhodes (2004) says that Technical depth and 3-5 years of work experience in a discipline before systems training can be the potential enabler to systems thinking development. For the point 10, Frank, M. (2006) says the interfaces should be additional roles of (junior) systems engineers. In summary, the point 3, 'to reduce re-bridging, and repetitive work, optimize the efficiency of the structure.' and point 7, 'Can work as single SE, but also can work as a member of SE team to do the group decisions. And sometimes group decisions can avoid errors and improve plan quality.' can be regarded as new findings of systems engineers traits in the interviews.

**Product manager**

*1. Understand outside stakeholders requirements.*

*2. Analyze the problems from a user perspective.*

*3. Consider more about the requirements plan but not technical plan.*

*4. Often make higher requirements then do compromise.*

*5. Check the problems in a bottom- top way.*

*6. Build requirement plan but do not need to build system plan in detail.*

The product managers' traits are concluded from interviews 3, and 7. Although sometimes they share similar responsibilities with systems engineers to guide and control the total project development directions, they do not need to build a too complex system. And the products focused by the product managers often face a fast iteration market. They do not need to get too involved with technical problems as well.

**Outside Stakeholders**

*1. Often change requirements or increase requirements,*

*2. Often has different minds with SE or product managers (think highly of business),*

*3. Think highly of economy, and the budget cost is very important,*

*4. The requirement on products is also related to companies practical ability,*

The outside stakeholders are mentioned in interview 2, 3, 6, 7. And they play a quite important role in product development.  And the direct leaders from the upper part are also related to these traits. The traits are concluded from the interviews and these interviews share similar impressions with the outside stakeholders. These groups should be stressed in later problem analysis.

**New employees，students**

*1. The knowledge is still staying at book level.*

*2. Has a series of core methods in his discipline.*

*3. Often face multidiscipline works and need to more study.*

*4. Face barriers between disciplines, such as jargon, and sometimes face communication problems about that.*

*5. Has different preference on how the information is transferred, designers and mechanical prefer graphics, but some engineers prefer data.*

The students are also involved in the interviews, especially interviews 1,4,5. They can be concluded as starter employees in the companies. They often have different minds comparing the experienced ones, listening and analyzing their ideas are also meaningful. Some of their suggestions about multidiscipline cooperation are regarded as inspirations for later analysis.

## 1.4.3 Problem in development

After analyzing 7 participants interview recordings, the main problems in the systems design development in their companies are concluded:

Main problems in development
*1. The requirement changes from the outside stakeholders.*
*2. Problems with adaptions between practical development and design requirements.*
*3. Different subsystems cannot compromise with each other, and sometimes conflict with each other.*
*4. The system plan is not mature, and brings repetitive work and low efficiency.*
*5. The subsystem engineer has problems in understanding system requirements.*
*6. New engineers, designers have problems to cope with multidiscipline problems*
*7. Different disciplines engineers have problems in communication because of jargon.*
*8. Different disciplines engineers have different preferences of information transfer.*
*9. Problems of profits distribution.*

The problems in development are concluded from the descriptions and answers from interviews' second level- problem and problem solving part. That part in each interview focuses how what problems participants meet and how they solve problems in multidiscipline cooperation. The problems No 1, and 5 are mentioned 3 times in the interviews, the problems No 2, and 6 are mentioned 2 times in the interviews. The other ones are strongly stressed by specific interviewees. These concluded problems will give support for next phase's designing the interaction frame.

## 1.4.4 Solutions from participants for problems

Facing the problems concluded, the stakeholders also give their own solutions from the interview descriptions:

**Table 1.4, The participants' solutions for the problems**

| *Problems* | Solutions from the stakeholders |
|---|---|
| *Problem 1: The requirement changes from the outside stakeholders* | Bridge the information gap and consider from the stakeholders side;<br>Design a compatible and robust system to face the change of requirements. |
| *Problem 2: Problems with adaptions between practical development and design requirements* | Propose reasonable design requirements, the reasonable design means it does not exceed the limits of what the team can achieve too much now. and sometimes propose reasonable higher design requirements. |

| | |
|---|---|
| *Problem 3: Different subsystems can not compromise with each other, and sometimes conflict with each other* | Define product properties.<br>Enhance different disciplines engineers' communication.<br>Give higher requirements then compromise |
| *Problem 4: The system plan is not mature, and brings repetitive work and low efficiency* | Design the system precisely, SEs and System architects can do group decisions to reduce error.<br>Improve compatibility of the system.<br>Using 6 sigma theory |
| *Problem 5: The subsystem engineer has problems in understanding system requirements.* | Reduce the information gap, Systems engineers and product managers must have related disciplines and can make evaluations for subsystem engineers' work. |
| *Problem 6: New engineers, designers have problems to cope with multidiscipline problems* | Read literature, make sure core methods of his own discipline, combining relative knowledge to multidiscipline objects. |
| *Problem 7. Different disciplines engineers have problems in communication because of jargon.* | Currently no solution |
| *Problem 8. different disciplines engineers have different preferences of information transfer.* | Currently no solution |
| *Problem 9. problems of profits distribution.* | Better reward regulations in the companies. |

For the problem of how the stakeholder deal with the loop of investigating the problem and defining the solution, the interviewers give their solutions in their works:

**Table 1.5, The participant solutions for the loop**

| | |
|---|---|
| Interviewee 1 | Let go of the contraction factor |
| Interviewee 2 | Keep thinking, can only say that the compatibility of the methods is still not good enough |
| Interviewee 3 | Define high standards and compromise |
| Interviewee 4 | (Not involved) |
| Interviewee 5 | (Not involved) |
| Interviewee 6 | It's a validation engineer's problem. There are not too many cycles |
| Interviewee 7 | Evaluate from the bottom up |

## 1.4.5 The expectation from participants

In each interview, the third hierarchy of the questions is about what their expectations about the multidiscipline cooperation are. The answers from participants are collected and the points are shown below:

**Table 1.6, Two levels of stakeholders' expectations from the interviews**

| Expectation abstract | |
|---|---|
| *Level 1*:(mentioned several times by several participants) | 1. Stakeholders in the development group from different disciplines should acknowledge, recognize and understand each other.<br>2. There should be active communication, and intime feedback.<br>3. The purpose is aligned, the members should know the design goal.<br>4. Interfaces for communication should be clear. |
| *Level 2:* (stressed once by one or two participants) | 5. There should be different kinds of display ways<br>6. The information between different stakeholders is symmetrical.<br>7. Trust between different stakeholders should be increased.<br>8. The execution of the development plan should be effective.<br>9. Higher working efficiency. |

# 2. A3AO Functionality analysis

## 2.1 Introduction of A3AO

According to Daniel Borches (2010),

‘ An A3 architecture Overview, as is shown in Figure 2.1, is a tool designed for knowledge sharing and effective communication of architecting knowledge. An A3 Architecture Overview provides a framework in which key architecture information obtained during reverse architecting process is consolidated in order to share architecture knowledge.’

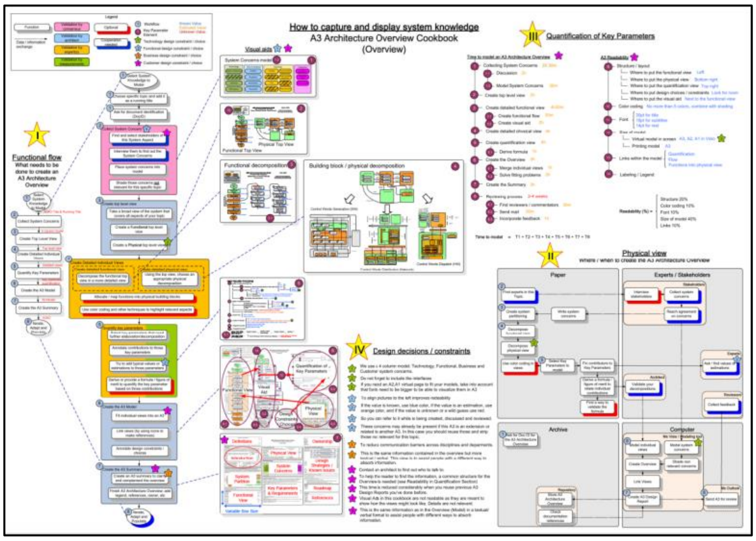



**Figure 2.1-1, A structured model, According to Danial Borches (2010)**

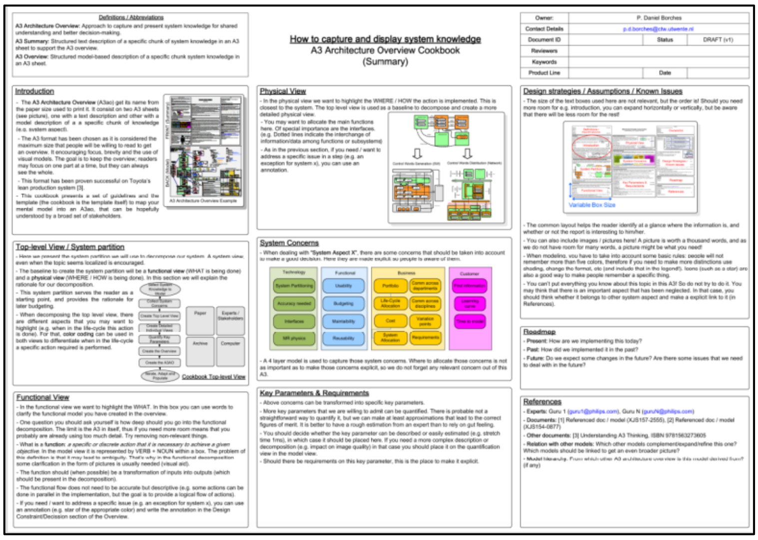



**Figure 2.1-2, A3 summary, According to Daniel Borches (2010)**

‘An A3 Architecture Overview uses two sides of an standard A3 paper size. One side displays a structured model (A3 Model), composed of several interconnected views, while the other side displays structured textual information(A3 summary). The A3 architecture Overview integrate multiple pieces of architecture information from different sources into a predefined

structure to provide the reader a coherent picture of a system aspect.'
' The goal of the A3 architecture Overview is to enable sharing of architecting knowledge by using a format that encourages it use, and to enable effective communication by providing an architecture overview in a fashion that can be understood by a wide variety of stakeholders.'

A3AO can also be regarded as a compact toolbox of using systems engineering approaches. The procedure of creating A3AO is also a process of conducting systems architecting. When building A3AO main components, varies of systems engineering tools/ systems engineering thinking approach are used.

## 2.2 Definition of A3AO functionality

According to A3AO creator, Daniel Borches (2010), proposes a series of standard steps to guide the A3 Architecture Overview creation. And these steps are the basis of the A3AO functionality, Hooft, D.T (2020,) advances and sorts clear steps of creating A3AO, the alternatives steps are increased and the A3AO structure become more inclusive, and each step has its function and goal to complete systems engineering process. The steps are shown in Figure 2.2. In practical use of creating A3AO, which steps are going to use, what kind of order they are organized are flexible. Based on the steps Hooft tailored, *the A3AO functionality can be defined as the suggested or optional step of creating A3AO, which has a clear function and usage goal and can combine with each other to complete all A3AO process of systems engineering.*

**Defining a clear and concise title ensures that the goal and context of the overview is clear.**

With a title and subject in mind this step-by-step guide can be followed:

*1) Collect stakeholders and their (system) concerns; the need*

In this step the main goal is to extract 'the need' of the customer and stakeholders; their concerns. The stakeholder concerns and user needs should be filtered, and categorized by the systems architect. A stakeholder is defined as anyone who has interest and influence on the system(design).

**After this step a clear view on the customer needs is established and placed in the overview.**

*2) Create top level view; the what*

This step is divided into two parts and is applied to define the main system function and project context. In step 2A the top level view is created and the main system function(s) are determined and visualized. The system function is placed into context, how it fits in the environment and how it relates to other systems is shown. In step 2B the (project)background and/or an introduction is added. In this step all (textual) information needed to proceed with designing the system is added; a design philosophy or project boundaries could be added.

**After completion of step 1, 2A and 2B the A3AO consists of the user requirements, a project context (introduction and background) and an overview of the main system function(s) and how it fits in the whole. This part of the A3AO is completed early in the development cycle and ensures that early in the project a clear understanding of the system under design (SUD) exists.**

*3) Quantify key parameters, define the system requirements; the what*

In this step the 'top level view' is specified and the (main) system requirements are determined. The system requirements must be related to the stakeholder and system concerns.

**After this step the system requirements are clear and placed in the architecture overview. Step 2 and 3 create a view on 'what' the system must do, and form the basis for the functional decomposition.**

*4) Decompose top level view; the how*

Define which functions are needed to fulfil the main system function. Make a visual representation of the system functions by using block diagrams or function trees, name or number each function.

**After this step it is clear how the main system function could be achieved, for the engineering department it is clear which functions need to be developed.**

*5) Complete the A3 model; detail specification*

In this step visual aids (step 5A) and the physical view (step 5B) are added to the overview.

5A) Add visual aids: figures, models and sketches could be added to elaborate on the functional model. In this step all information, diagrams or figures are added to elaborate on the functional decomposition such that it is clear what must be designed by the engineering department.

**After step 5A the 'system design' is complete and it is clear what the system must do. After step 5A the engineering phase could start.**

5B) Physical view: in the physical view the implementation of the function(s) are displayed. In this view how the function(s) are fulfilled is shown. This step is executed during the engineering process.

**Completion of step 5B gives the complete picture on the actual system solution.**

*6) Complete A3 summary; detail specification*

In this step all (relevant) knowledge created during the development process is added to the overview. Capture knowledge related to the system ('lessons learned') and the design decisions and rationales are added. Besides this, other information (e.g customer information, product specifications) and knowledge the architect finds important should be added. Lastly the overview is completed by adding references and the complete overview should be checked for cohesion and completeness.

**After this step the overview is complete and (design) knowledge is captured.**

*7) Share adapt and store the A3AO; using the overview*

An A3AO is used to share (communicate) the architecture of the system under design. An important step is to share this document (to stakeholders, to meetings and for example on a whiteboard). If relevant feedback is collected the overview could be adapted. Furthermore, the overview must be stored on a convenient and easy to reach location.

**This step is all about using and sharing the document. Especially when introducing A3AOs in the organization sharing and gathering feedback is a critical aspect.**

**Figure 2.2, Systems engineering; Tailored A3AO approach step-by-step guide, Hooft, D.T**

## 2.3 Analysis of the thinking types in functionality

This diagram shows a summary for the A3AO functionalities thinking track and types, the detail description is on the following.

**Table 2.1, The A3AO functionalities thinking track and thinking types**

| A3AO Functionality | Thinking track | Thinking type |
|---|---|---|
| Stakeholders and System concerns | Collect, sum up, summarize | Sum |
| Top view | Abstractly infer | Sum |
| Parameters and system requirements | Refine, infer, list | Sum |
| Decompose of Top view- functional view | Divergent infer | Expand |
| Physical view/N2 diagram | Refine, abstract infer | Sum |
| Fun key | Evaluate infer | Evaluate |
| Design strategies | Divergent infer, integrate infer | Expand |
| Roadmap | Predicting infer | Evaluate |

According to the research questions,21
'1. How to achieve a continuous, complete interaction frame and logic to get complete presentation and operation of A3AO on large screen devices?
1.1 How to achieve a general interaction frame, including the components of the layout logic, operation, guide and switch and so on, to cover the full phases of review, using and feedback/monitor of A3AO?'
If we want to build a general and complete interaction for A3AO, how to deal with the main components of A3AO- functionalities are a quite important question. This research chooses to find the similarities and differences between the functionalities and distribute them into different types. We decide to begin with the A3AO functionalities thinking trajectory and actions.

The way we choose to analyze is to reproduce the trajectory and actions of thinking in user's mind when user use these A3AO functionalities. It is important to analyze how systems engineers thinking trajectory runs during using functionalities and we can try to conclude the Functionalities into three main types.
The functionality of the *Stakeholders and System concerns* thinking actions is much more about coping with information, to collect them, sum up them and summarize them, there is not too much inferring thinking inside. It works as a preparation functionality. The summary thinking is the leading thinking.
The functionality of the *Top view* plays important role in the total systems design. It should not be so complexed but should indicate how the systems run in a simplified and underlying logical way. That requires the systems engineers to get abstract inferences of the common logic between a lot of simulated phenomena and possible system functions and behaviors. It

gives high requirements on inferring ability and concluding ability. The abstractly inferring is the main thinking track when using Top view in A3AO.

The functionality of *Parameters and system requirements* gives limitations to the systems and their functions. The procedure to get these parameters and requirements is not a short way. It needs to refine the parameters and a lot of requirements between a mass of information, and some of them need a lot of inference to finalize, then to list and organize them in a logical way. The thinking track of this functionality focuses on refining/defining and inferring from the information available. The summary thinking is still the leading thinking when using *Parameters and system requirements*.

The functionality of the *Functional view* is an important part of A3AO and in total systems design, it is also an indispensable phase. The functional view is produced by combing the *Top view* and subsystems to get the functions of the systems. The internal relationships between functions are also clearly outlined by *Functional view*. The divergent inferring is the main thinking track when systems engineers using the *Functional view*. The systems engineers do infer by expanding top view and subsystems into detailed functions, from simplified underlying logic and restrictions to multiple and specific items. The expanding thinking track leads the minds when using this *Functional view*.

The *Physical view* is relating systems to the physical world. It can be realistic graphics when implementing the systems into realistic engineering outcomes in a physical perspective. It can also be concluding the relationship between the systems and the physical world. When doing the latter analysis, the refining and summarizing thinking track leads to the creating phase.

The *N2 diagram* is a functionality that relates to clarify and create interfaces between the system's elements, which can be functions, behaviors, physical objects and so on. And the thinking track of *N2 diagram* is strongly related to how you use it, if the interfaces are already existed and ensured, the summarizing thinking is the mainly used. If the interfaces are not clear, and *N2 diagram* is used to generate and organize them, the expanding thinking can be the leading track.

The *Funkey* is proposed by G.M.Bonnema (2008), it is a functionality that is related to measure the functions. The functions are important components in system design, the Funkey can help us to measure and predict functions from various layers. After that, the clarified and measured functions can help the systems design be clearly, precisely and logically organized. In this A3AO functionality, evaluating inferring is the main thinking track.

The *Design strategies* is a functionality that to draw design guidance for the systems. The design strategies are different from other systems components, they should be related to practical and detailed engineering and design situations. It is much more about coming from the limitations, then getting strategies with other levels' limitations. When using *Design strategies*, the divergent inferring and integrate inferring are both used, but totally, the expanding thinking still leads the thinking track, especially in the phase of generating strategies from limitations.

The *Roadmap* is the functionality that mapping the systems in the past, current, and future solutions. The predicting infer is the main thinking track when using this functionality. It is easy to make judgments that the *Roadmap* is an A3AO functionality that is led by evaluating thinking.

The thinking tracks of different functionalities are already analyzed, and we can find that some functionalities share a lot of similarities in thinking. We can use these similarities to simplify and organize the using process of A3AO functionalities effectively.

## 2.4 Different kinds of thinking types

Although the functionalities in A3AO have differences, they can be concluded as 3 thinking types:
3 type thinking ways of the A3AO functionalities.

- *To summarize and abstract*: abstract from information pack, phenomenon, collected materials and so on.
- *To expand and specify*: expand from current items or layers to more items and layers.
- *To evaluate and judge*: evaluate or measure items from a lot of perspectives.

They are combining with each other to complete the full system thinking circle.

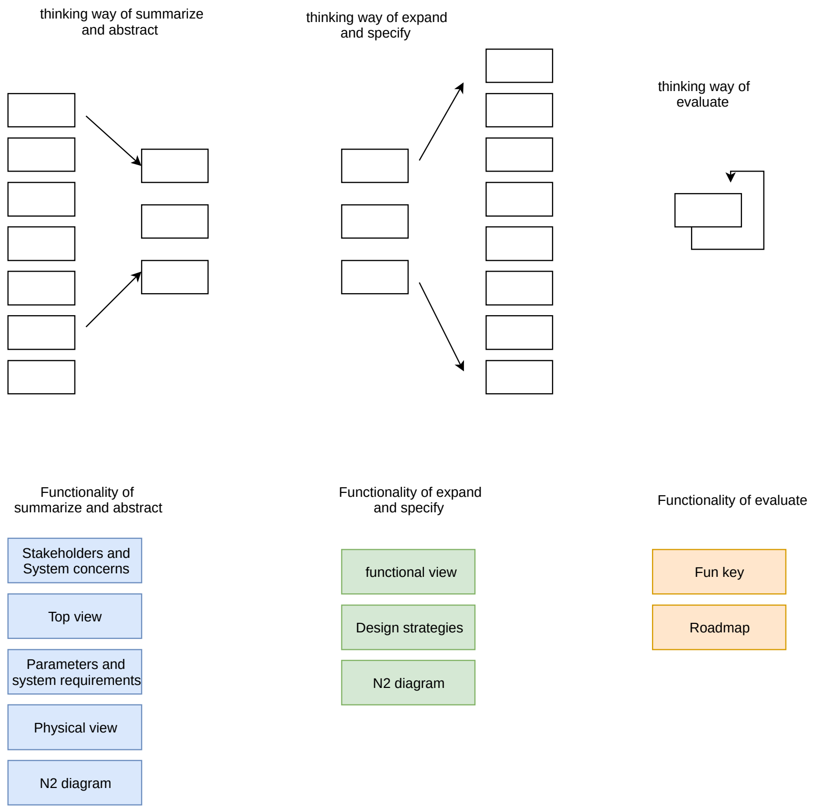



**Figure 2.3, Visualization of the thinking types and each thinking's related functionalities**

## 2.5 Inference

Based on the thinking types concluding, there are inferences about using these thinking types to organize and use the A3AO in a creative and efficient way:

*1. There exists a loop to summarize, expand and evaluate.*

*2. The functionalities which belong to the same thinking category can change order in a limited range.*

*3. The circle is the unit combining with the summarize category functionalities, expand functionalities, and evaluate functionalities. Each category can be interchangeable and each category can have multiple functions*

*4. Multiple loop units can combine with each other to meets the total requirements to summarize, expand and evaluate.*

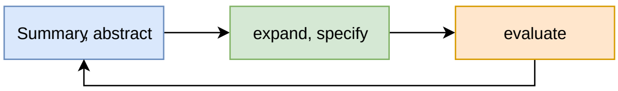



**Figure 2.4 The loop of to summarize, expand and evaluate.**

# 2.6 Combinations of functionality loops

According to the inferences, we can organize the functionalities in several ways.

## 2.6.1 Single loop

If the user of A3AO wants to do a quick system design, choosing one from each thinking type is the most efficient method. These combinations also serve as the basic unit of the using circles. The examples are shown in Figure 2.5.

For example, the first circle, beginning from stakeholders and system concerns, then according to stakeholder requirements, we can directly build the functions we need, and then using fun key to evaluate the functions that we create to clarify the importance levels of the functions. This one is general use for building systems.

There is also a common use for system building is directly create the summarized the top view, then expand it to functional view. (the second one in the Figure) A basic functional system is built. After that, we can use the roadmap to predict the systems frame development in current times and futures

We can also use the stakeholders and system concerns firstly, then according to that we can directly use design strategies from expanding category functionalities, after that, using roadmap to evaluate the design. (the fifth example in the Figure) This case is usually used in design discipline solutions.

According to the circle of summarizing, expand and evaluate, we can also begin with the fun key. Sometimes we already know the functions we need, using fun key to make clear of the functions priority and pros, then we can use that to specify the parameters and system requirements, After that to build the functional view. This using way is also possible.

All the circles in the pictures are reasonable and flexible, and they should be well chosen according to the practical solutions.

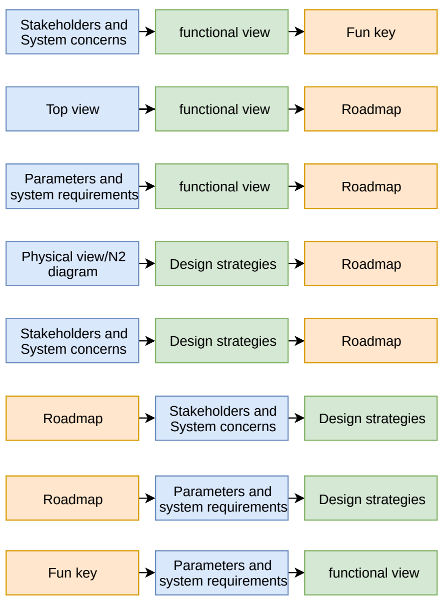



**Figure 2.5, Example of the simple loop of the functionalities**

## 2.6.2 One loop with multiple functionalities

If users want to do a more in-depth design but do not want to change their thinking types frequently, they can choose to use one circle but to integrate multiple functionalities in each phase. The examples are shown in the Figure 2.6.

For example, we can use the stakeholders and system concerns, top view, parameters, and system requirements from the summary functionality category firstly, we can get all the limitations, summary for the system, Then, we can use functional view and design strategies to expand and specify them. After that, roadmap can be used to predict the system performance in the current and future.

There are also a lot of examples in the picture below, they are not fixed. It should be stated that this kind of use can give deeper analysis and system building, but do not to change thinking types frequently. They are both rich in deep architecting and continuous in thinking tracks and types.

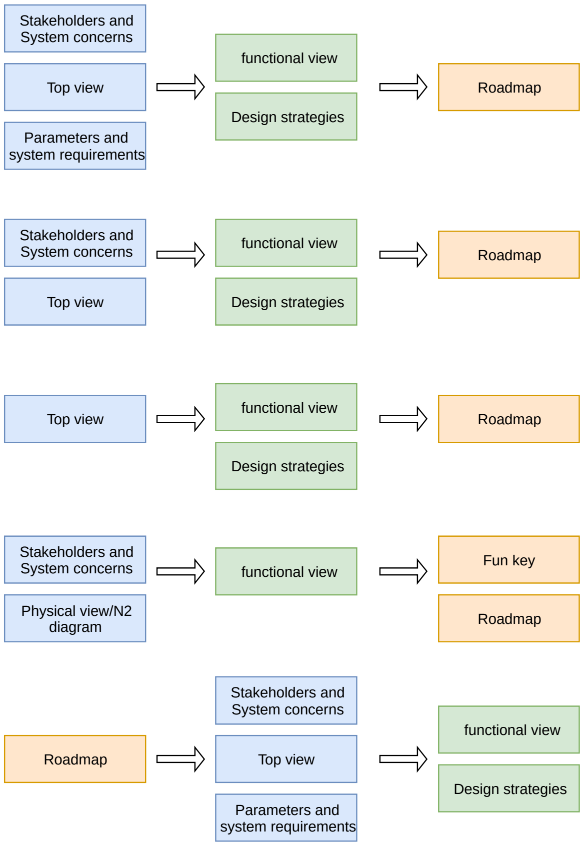



**Figure 2.6, One loop with multiple functionalities**

## 2.6.3 Several loops integrate with each other's

This kind is to integrate several loops of summarize, expand and evaluate. The several loops integrated with each other is more complicated but more realistic in practical use. The examples are shown in the Figure 2.7.

For example (the first one in the Figure), for the first loop begin with the stakeholders and system concerns, and top view, then usage follows with the functional view, a basic system is already built. After that, the fun key is used to evaluate the system functions. The first loop is already finished as an evaluated functional based system. Then we can begin the second loop, the parameters and system requirements are used firstly to give system limitation again in a parameters level. And the later design strategies are a more comprehensive deeper expanding for the system building. A deep and complete system is already built, we can use roadmap to predict its performance in the current or the future.

There a lot of possible using solutions, the Figure below just shows some of them. The usages of loops really related to practical system cases.

This kind of use is more in line with the experiences of spiraling model in system development. It may sometimes take much time but result in a more complete and deeper system architecting.

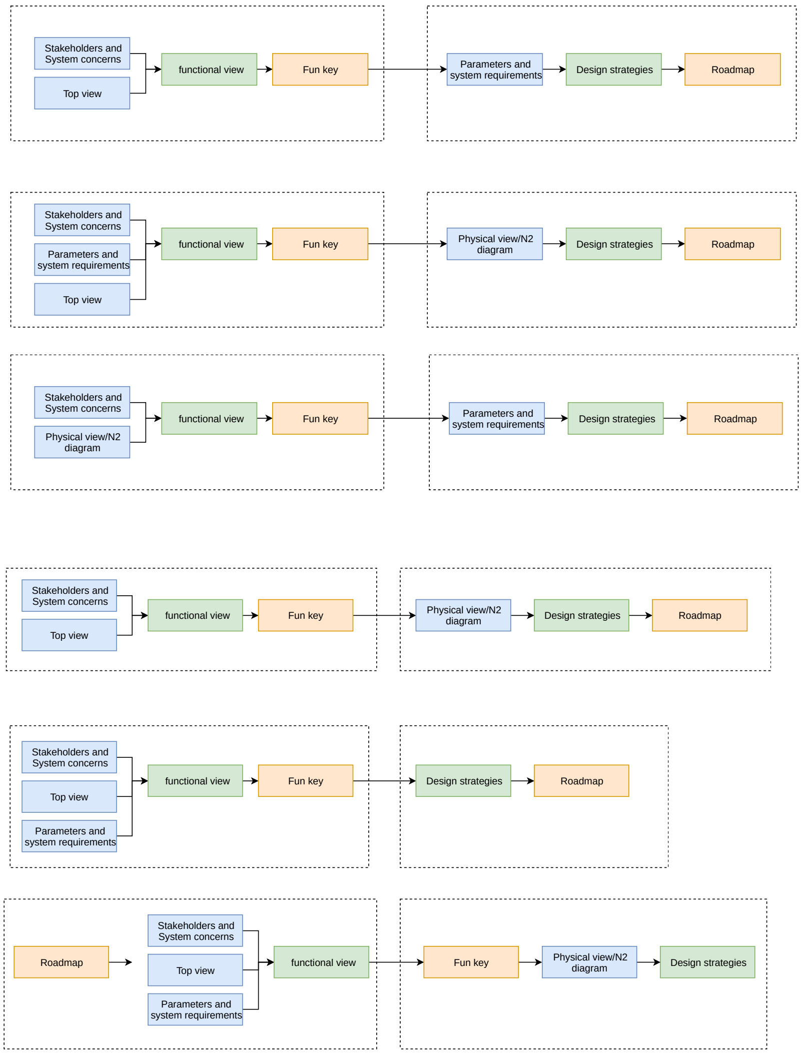



**Figure 2.7, Several loops integrate with each others**

# 2.7 Some tips of the combinations of functionalities

There are tips when using these functionalities when we use these inferences. These tips are related to practical system building experiences and can avoid unrealistic use of functionalities. They are based on internal relations between the A3AO functionalities and are suggested to be considered before organizing the functionalities' usage. These tips and make the inferences and the loops run more fluently and completely.

*1. Stakeholders and system concerns are strongly suggested to be used at the beginning.*
*2. Fun key is strongly suggested used together with the functional view.*
*3. Design strategies is suggested to put at later part.*
*4. Top view should be put before functional view*

# 3. Platform design and functionality decomposition

## 3.1 A3AO functionality

In section 2.2, we base on the steps Hooft tailored (shown in Figure 2.2 ) work, gives the definition of A3AO functionality. The *A3AO functionality can be defined as the suggested or optional step of creating A3AO, which has a clear function and usage goal and can combine with each other to complete all A3AO process of systems engineering.*

In section 2.4, this research proposes a using circle of functionalities based on tracking the thinking trajectory of using functionalities. The functionalities are concluded as three main categories, to summary, to expand and to evaluate. And there exists a using circle of using the functionalities.

These two important backgrounds are the basis of this chapters analysis.

**Defining a clear and concise title ensures that the goal and context of the overview is clear.**

With a title and subject in mind this step-by-step guide can be followed:

*1) Collect stakeholders and their (system) concerns; the need*

In this step the main goal is to extract 'the need' of the customer and stakeholders; their concerns. The stakeholder concerns and user needs should be filtered, and categorized by the systems architect. A stakeholder is defined as anyone who has interest and influence on the system(design).

**After this step a clear view on the customer needs is established and placed in the overview.**

*2) Create top level view; the what*

This step is divided into two parts and is applied to define the main system function and project context. In step 2A the top level view is created and the main system function(s) are determined and visualized. The system function is placed into context, how it fits in the environment and how it relates to other systems is shown. In step 2B the (project)background and/or an introduction is added. In this step all (textual) information needed to proceed with designing the system is added; a design philosophy or project boundaries could be added.

**After completion of step 1, 2A and 2B the A3AO consists of the user requirements, a project context (introduction and background) and an overview of the main system function(s) and how it fits in the whole. This part of the A3AO is completed early in the development cycle and ensures that early in the project a clear understanding of the system under design (SUD) exists.**

*3) Quantify key parameters, define the system requirements; the what*

In this step the 'top level view' is specified and the (main) system requirements are determined. The system requirements must be related to the stakeholder and system concerns.

**After this step the system requirements are clear and placed in the architecture overview. Step 2 and 3 create a view on 'what' the system must do, and form the basis for the functional decomposition.**

*4) Decompose top level view; the how*

Define which functions are needed to fulfil the main system function. Make a visual representation of the system functions by using block diagrams or function trees, name or number each function.

**After this step it is clear how the main system function could be achieved, for the engineering department it is clear which functions need to be developed.**

*5) Complete the A3 model; detail specification*

In this step visual aids (step 5A) and the physical view (step 5B) are added to the overview.

5A) Add visual aids: figures, models and sketches could be added to elaborate on the functional model. In this step all information, diagrams or figures are added to elaborate on the functional decomposition such that it is clear what must be designed by the engineering department.

**After step 5A the 'system design' is complete and it is clear what the system must do. After step 5A the engineering phase could start.**

5B) Physical view: in the physical view the implementation of the function(s) are displayed. In this view how the function(s) are fulfilled is shown. This step is executed during the engineering process.

**Completion of step 5B gives the complete picture on the actual system solution.**

*6) Complete A3 summary; detail specification*

In this step all (relevant) knowledge created during the development process is added to the overview. Capture knowledge related to the system ('lessons learned') and the design decisions and rationales are added. Besides this, other information (e.g customer information, product specifications) and knowledge the architect finds important should be added. Lastly the overview is completed by adding references and the complete overview should be checked for cohesion and completeness.

**After this step the overview is complete and (design) knowledge is captured.**

*7) Share adapt and store the A3AO; using the overview*

An A3AO is used to share (communicate) the architecture of the system under design. An important step is to share this document (to stakeholders, to meetings and for example on a whiteboard). If relevant feedback is collected the overview could be adapted. Furthermore, the overview must be stored on a convenient and easy to reach location.

**This step is all about using and sharing the document. Especially when introducing A3AOs in the organization sharing and gathering feedback is a critical aspect.**

**Figure 2.2, Systems engineering; Tailored A3AO approach step-by-step guide, Hooft, D.T**

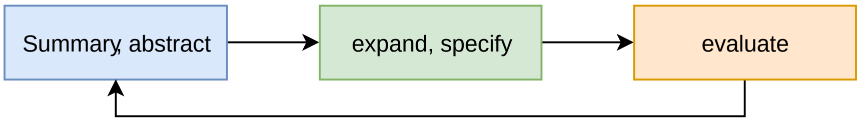



**Figure 3.1, The loop of to summarize, expand and evaluate.**

## 3.2 Why the functionality needs to be decomposed.

According to the research approach, the first point of research propose is
'1. Exploration of A3AO achieving continuous interaction operation and complete full cycle using experiences in large screens.'
The continuous interaction operations include the phase of creating the A3AO, and the functionality is related to the creation procedure. But in the interaction, how to build the A3AO by using functionalities is a problem that needs to be solved. And how to integrate the creation of functionalities inside the interaction is also a question. To integrate the functionalities creation into interactions needs to build a platform that using components to help to shape functionalities. Platform design method could be the inspiration.
There is an inspiration according to platform design method that functionalities can be decomposed into some components and sections. These components can combine with each other to help to shape the functionalities and the components are easy to create, edit and operate. That is the reason of why functionality needs to be decomposed.

## 3.3 Platform design method

According to Mc Grath (1995), the product platform definition is 'a set of subsystems and interfaces that form a common structure from which a stream of related products (product family) can be efficiently developed and produced'. According to Baldwin, C. Y., Clark, K. B., & Clark, K. B. (1999), characteristics of product platforms are modular product architecture, interfaces (interaction between modules), standard design rules.
Halman, J. I., Hofer, A. P., & Van Vuuren, W. (2003) introduces the relationship of using standard components to form product platforms in figure 2. This figure 'shows the relationship between components commonality within the same and among different types of power tools, and brand segmentation.'

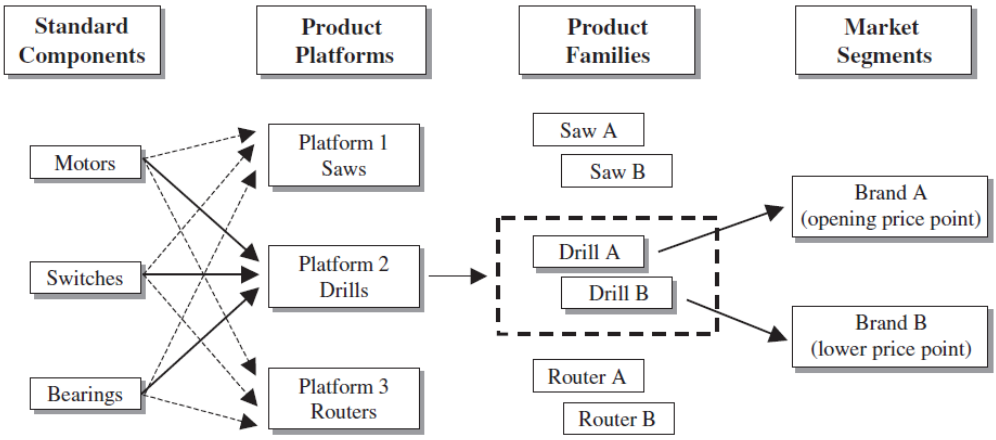



**Figure 3.2, Platform-Based Development of Product Families within Skil by Halman, J. I., Hofer, A. P., & Van Vuuren, W. (200IN3)**

In our research, the A3AO functionalities could be regarded as the 'product platforms' in the Figure 3.2, the combinations of different A3AO functionalities can be regarded as the 'product families' in the Figure 3.2. But what could be the standard components to form the A3AO functionalities remains to be answered in later steps. To get standard components, decomposing A3AO functionalities into detailed actions of operations, then abstracting these operations into standard steps based on the A3AO three kinds of category definition (summarize category, expand category, and evaluate category) could be a good choice.
And these standard components will work as inspirations, and have potential to be processed into tools that can create the A3AO. The tools are shown in section 5.5.

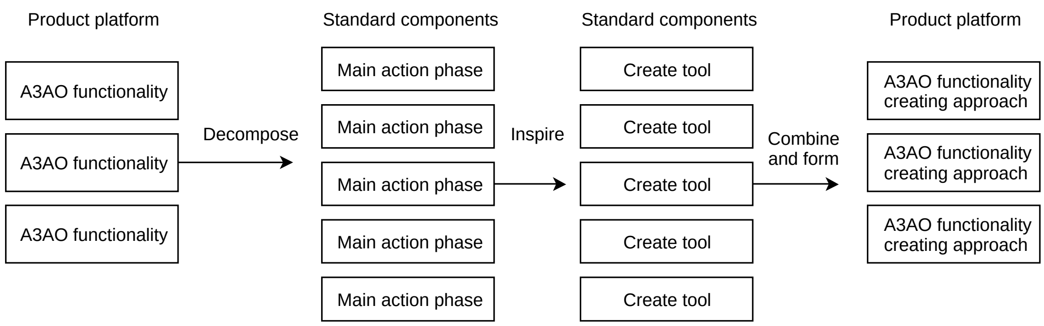



**Figure 3.3, Platform design in this research**

As is shown in Figure 3.3, the total process of how the platform design method is used in this research is:

*1. A3AO functionalities' decomposition into actions, actions are concluded the main action phases. (From product platform to standard components).*

*2. Main action phases inspire inventing the create tools and some of them are generated into create tools to create A3AO, this part will be shown in design chapter. (From standard components to standard components)*

*3. These tools combine and form the platform of creating A3AO. (From standard components to product platform)*

## 3.4 Functionality decomposition overview

After making sure that there is a need to decompose the functionality and find the standard components which are inspired by platform design method, it still remains a question that how to decompose and visualization the composition. In this section, steps of decomposition and finding the defined ‘standard components’- main action phase are introduced by the figures below. And it will also help to understand and read later practical functionality decomposition overview figures.

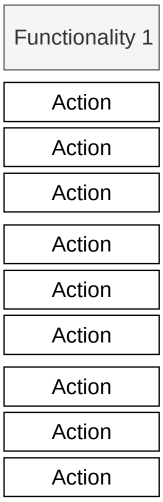



**Figure 3.4, Step 1**

As is shown in Figure 3.4, step 1 is to decompose the Functionality into actions. According to the Functionality definition in this chapter beginning: ‘the A3AO functionality can be defined as the suggested or optional step of creating A3AO, which has a clear function and usage goal and can combine with each other to complete all A3AO process of systems engineering.’ The functionality itself is a collection of actions to create the A3AO with a clear usage goal. So, what we need to do is to analyze them by a view of actions and decompose them into actions first. This is the main content of step 1.

As is shown in Figure 3.5, step 2 is to put the same category functionality and their actions on the same level in the paper. The reason why it is emphasized that choosing the same category is that the same category functionality has more similarities in thinking type, as is analyzed in the Chapter 2 Functionality analysis. It also means that same category functionalities are more possible to find the standard components.

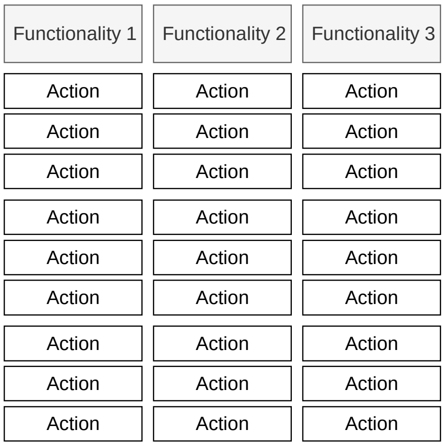



**Figure 3.5, Step 2**

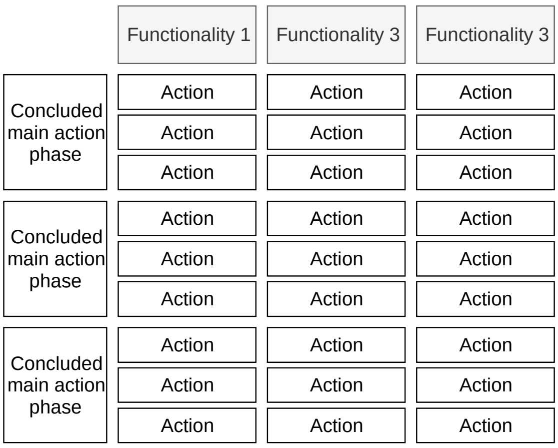



**Figure 3.6, Step 3**

As is shown in Figure 3.6, step 3 is to try to conclude the actions in the blocks among different functionalities from the horizontal direction. The concluded items are named as concluded main action phase, and they are the main goal of the functionality decompositions.

The Figure 3.7, Figure 3.8, Figure 3.9 are the functionality decomposition overview from summarize, evaluate and evaluate category. And they all follow the steps described before. The details inside will be discussed later.

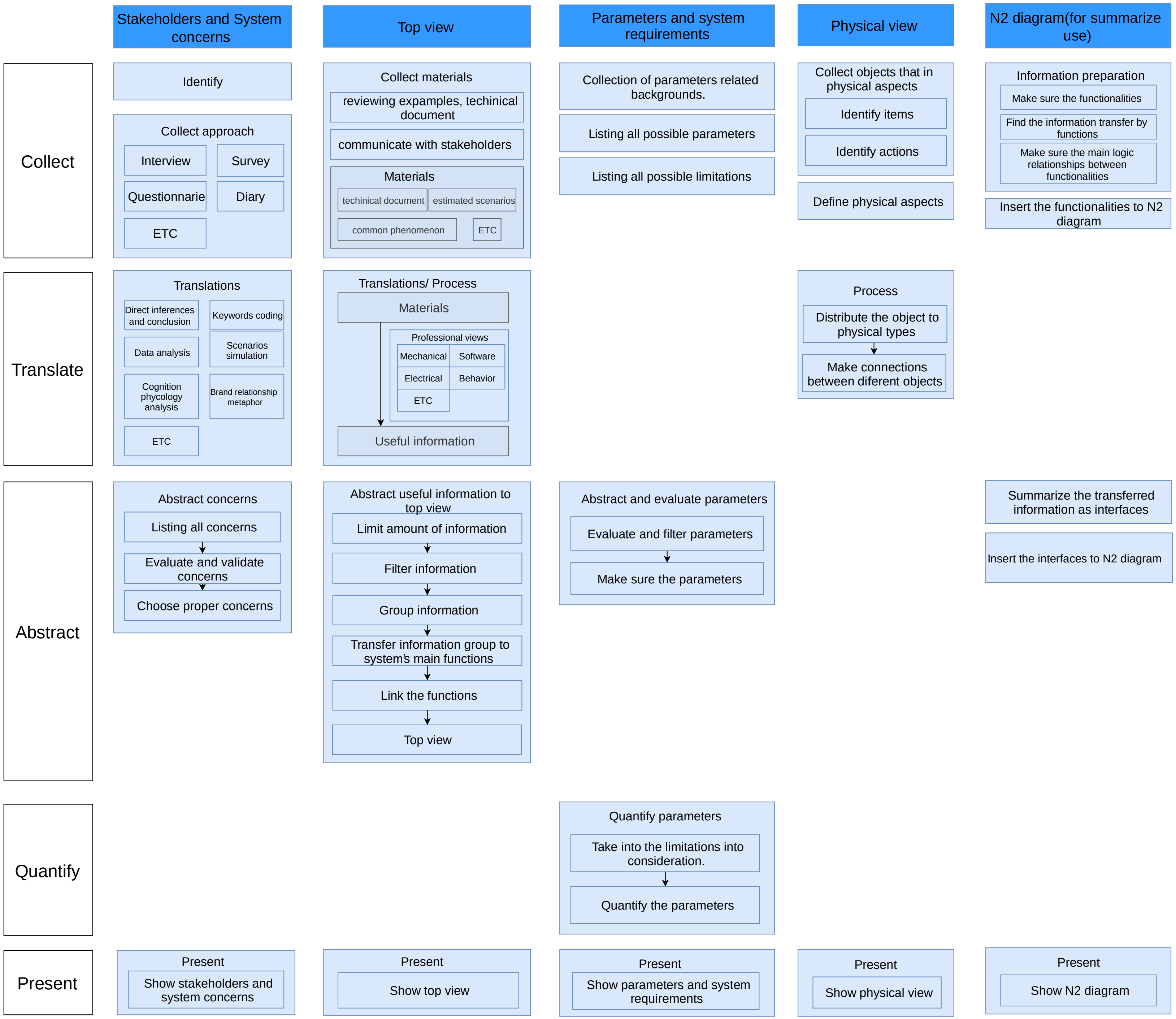



Figure 3.7, Summarize category functionality decomposition overview

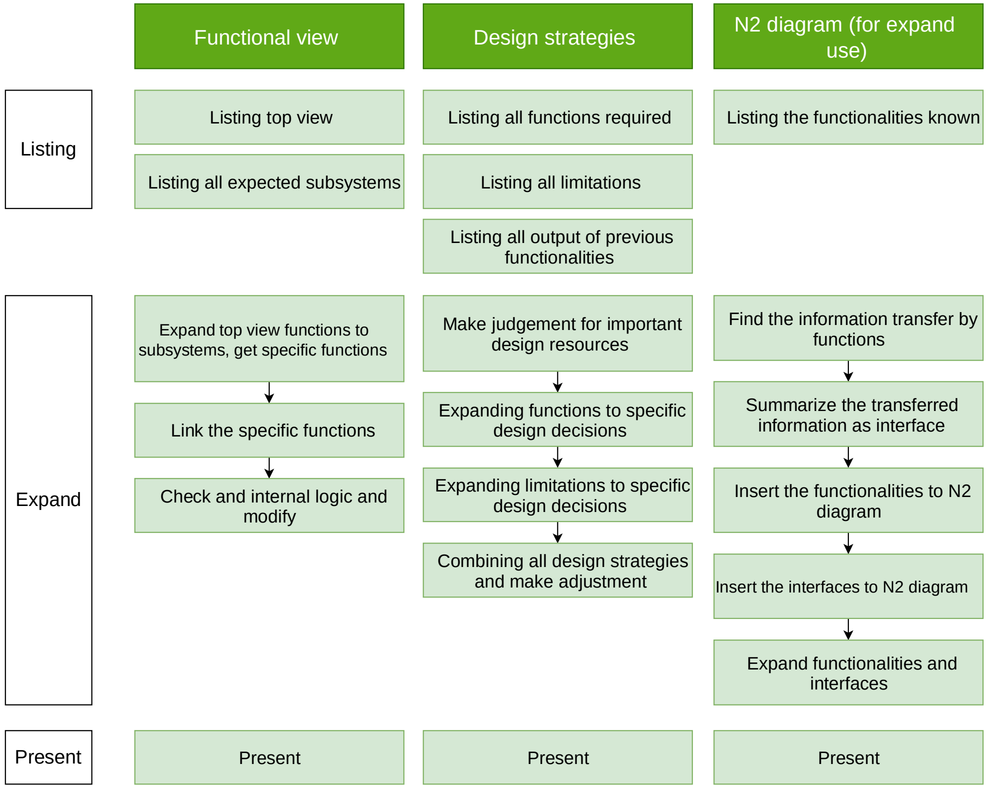



Figure 3.8, Expand category functionality decomposition overview

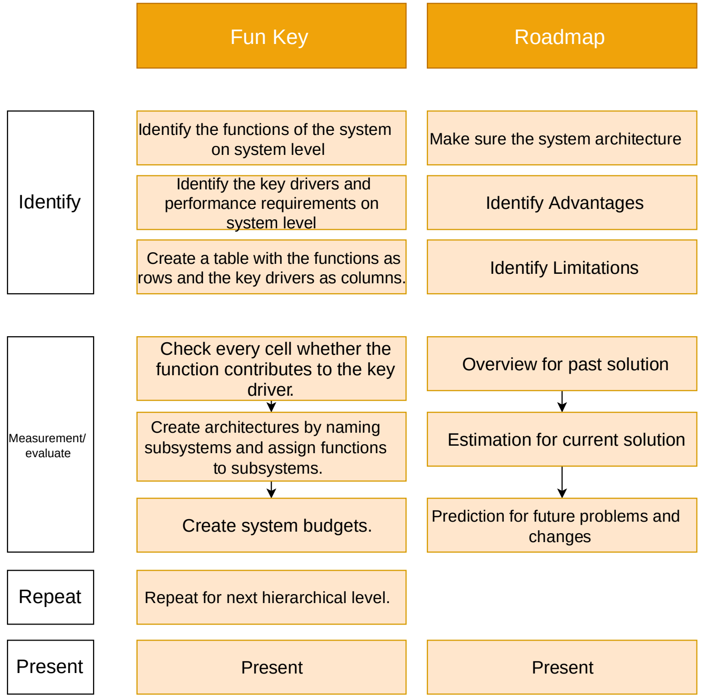



Figure 3.9, Evaluate category functionality decomposition overview

## 3.5 Summarize category functionality decomposition

For the summarize functionalities, most ones are decomposed into a series of actions, and these actions can be concluded as 5 main action phases: collect, translate, abstract, quantify, present.

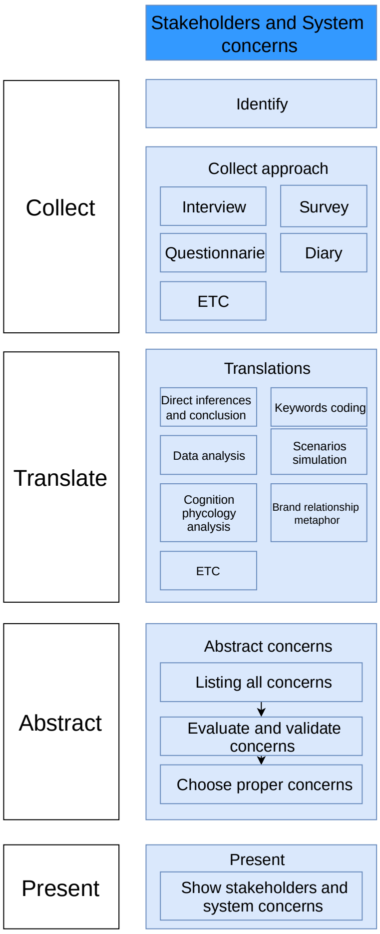



**Figure 3.10, Stakeholders**

### *Stakeholders and system concerns*

As is shown in the Figure 3.10, The first steps are to identify and to collect (a series of approaches are included: interview. survey, questionnaire, diary, ETC). Then these materials need to be translated into useful information, the approaches can be direct inferences, keywords coding, data analysis, scenarios simulation, cognition phycology analysis, brand relationship metaphor, ETC.

Then the following steps are to abstract concerns, those can be listing all concerns, evaluate and validate them and choose proper concerns. After that, we can present all stakeholders and system concerns.

### *Top view*

As is shown in the Figure 3.11, Top view is an important functionality in A3AO usage. The result of the top view will guide further development. But to get a correct and precise top view is not easy. There are a series of actions that can be taken to get an ideal top view.

The first part is still to collect materials, which can be got from reviewing examples, communication with stakeholders, and all related materials. Then it comes to the translation/process phase, we can use a series of professional perspective views (mechanical views, software views, electrical views, behavior views, and so on) to translate these materials into useful

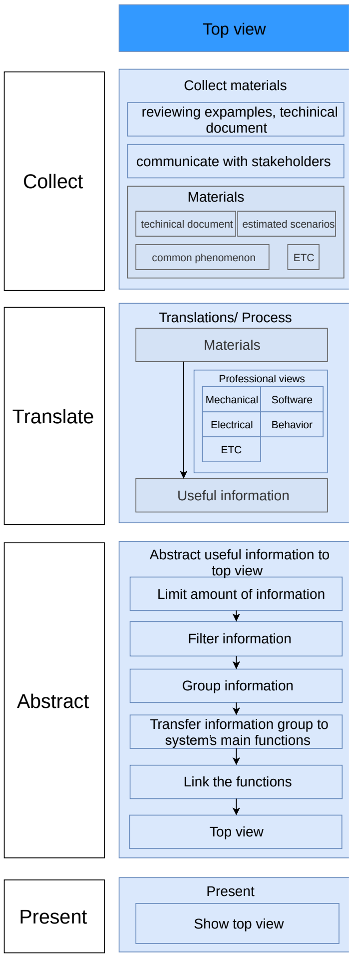



**Figure 3.11, The Top view**

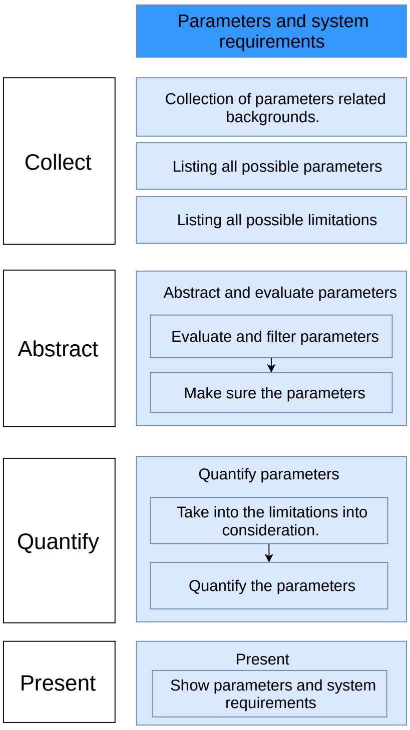



**Figure 3.12，Parameters**

information. Then, we need to take a series of steps to abstract useful information to top view, according to Borches (2010), the steps can be: limit amount of information, filter the information, group information, transfer information group intro systems' main functions, link the functions, get the top view, and present the top view.

***Parameters and systems requirements*:**

As is shown in the Figure 3.12, The actions to get the parameters start with the collection phase, which contain collection of parameters' related backgrounds, listing all possible parameters, listing all possible limitations.

Then we need to evaluate and filter parameters, then make sure the parameters.

The parameters also need quantifications, actions include taking the limitations into consideration, and quantify the parameters and systems requirements. Then we can present the parameters and system requirements.

***Physical view*:**

As is shown in the Figure 3.13, The physical view is to present the systems from a physical perspective. It also starts with the collection phase: collect objects that in physical aspects, define physical aspects. Then it needs the translation step of the procession: distribute the objects to physical aspects and make connections between different objects.

It also needs some steps to choose what to show in the physical view. After organizing visualization, we can present the physical view.

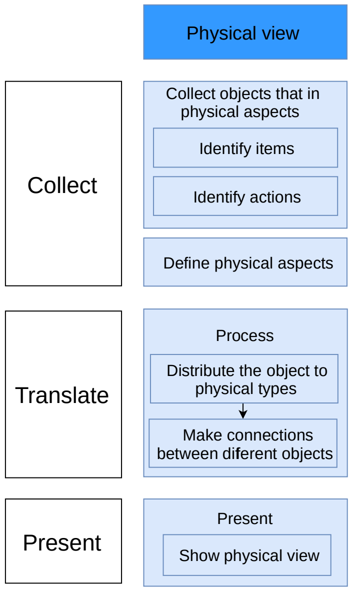



**Figure 3.13, Physical view**

***N2 diagram***

As is shown in the Figure 3.14, The use of N2 diagram is flexible, it can be for summarize use or expand use. It applies to systems interfaces, 'N2 diagram are a well-defined methodology and implementation tool used to facilitate the identification, communication, and documentation of system and system of systems interfaces, activities, interactions, and behaviors', according to Simpson, J. J., & Simpson, M. J. (2009). The N2 chart is firstly invented by Rober J. Lano (1977). From the action view, it starts with the collect steps: make sure the functionalities, make sure the main logic relationships

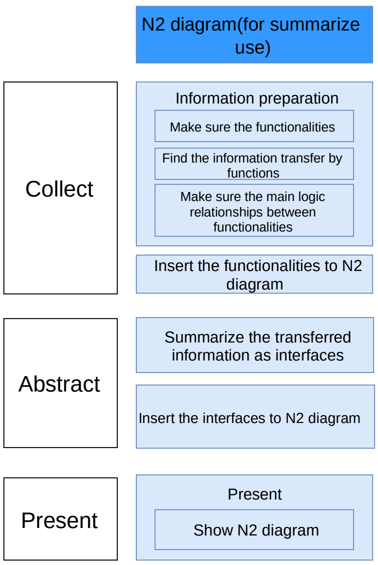



**Figure 3.14, N2 diagram**

between functionalities, and find how the information transfer between the functions. Then they follow the abstract steps: summarize the transferred information as interfaces, insert the functions/actions/items to N2 diagram, and insert the interfaces to N2 diagram. After inserting all elements and interfaces, we can present the N2 diagram.

## 3.6 Expand category functionality decomposition

For the expand category functionalities. The actions of these functionalities can be concluded as 3 main action phases: listing, expand, present.

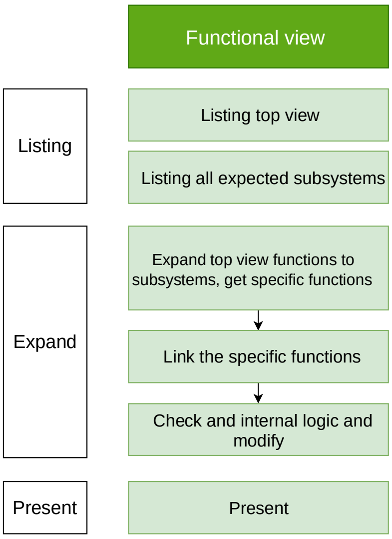



**Figure 3.15, Functional view**

***Functional view***

The functional view is referred to the Functional Flow Block Diagram (FFBD) in systems engineering, which can help to sequence the functions and find their internal relationships. According to Blanchard, B. S. and W. J. Fabrycky (1998), definition of function, 'Function is A specific or discrete action that is necessary to achieve a given objective.'

As is shown in the Figure 3.15, The functional view starts with listing steps: listing the functional view, listing all expected subsystems. Then we expand top view functions to subsystems and get specific functions, and we link these functions. After that, we check the internal logic and modify it. Then We can present the functional view.

***Design strategies***

As is shown in the Figure 3.16, The design strategies start with the listing steps: listing all the functions required, listing all limitations, listing all output of finished functionalities. Then we go to the expand phase: making judgments for important design resources, expanding the functions to specific design decisions, expanding the limitations to specific design decisions, combing all design strategies, and adjust. We can show the design strategies

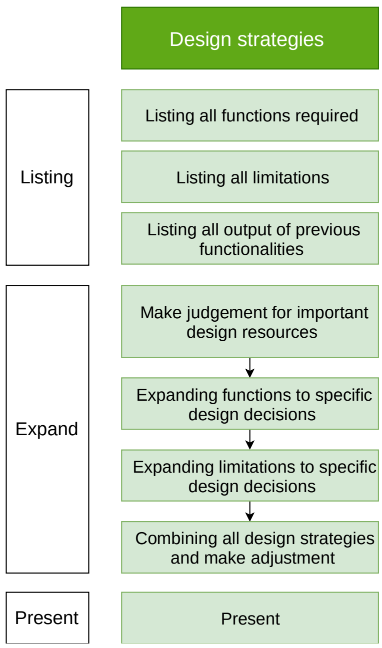



**Figure 3.16, Design strategies**

***N2 diagram***

As is shown in the Figure 3.17, The N2 diagram for expanding

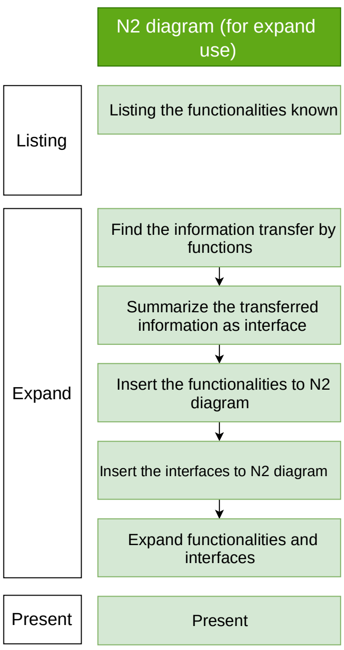



**Figure 3.17, N2 diagram**

use starts with listing steps: listing the functions known, listing all the actions/items known. Then we go to the expand steps: find the information transferred by functions, summarize the transferred information as interfaces, insert the functionalities to N2 diagram, insert the interfaces to N2 diagram, expand the functions and interfaces in the diagram.

## 3.7 Evaluate category functionality decomposition

Evaluate functionalities analysis are shown below.

The evaluate functionalities steps can be concluded as 4 main action phases： identify, measurement/evaluate, repeat, present.

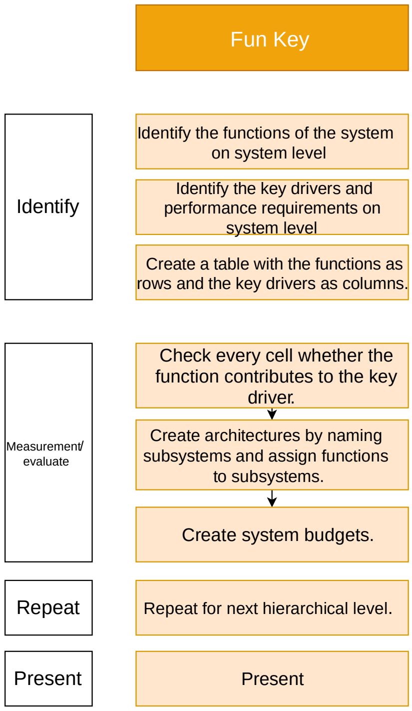



**Figure 3.18, Funkey**

***Funkey***

The Funkey is purposed by Bonnema, G. M. (2008), s is shown in the Figure 3.18, and proposed by Bonnema, G. M. Funkey begins with the identify steps: identify the functions of the system on system level, identify the key driver and performance on system level, create a table with the functions as rows and key drivers as columns.

Then we go to the measurement/evaluate phase: check every cell whether the function contributes to the key driver, create architectures by naming subsystems and assign functions to subsystems, and create system budgets.

After that, we repeat for the next hierarchical level. The main matrix of Funkey is finished, then we can present the funkey.

***Roadmap***

As is shown in the Figure 3.19, The roadmap starts with the identify steps: make sure the system architectures already have, and identify its advantages, identify limitations.

Then we go to the measurement/evaluate steps: we can do the overview for past solutions, do estimations for current solutions, and do predictions for future problems and adjustments.

After picturing all the review, prediction of the past, current and future, we can present the roadmap.

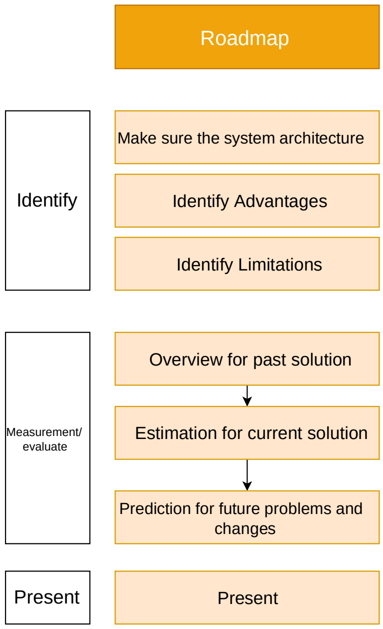



**Figure 3.19, Roadmap**

## 3.8 Inspirations

According to the platform design inspirations and its plan of application in our research, the 'standard components' of the A3AO functionalities could be regarded as concluded main action phases. Then what we should do is to analyze these concluded main action phases and get inspiration from them to support the design of creating tools of A3AO and using these tools to build a platform to create and edit A3AO. In this chapter, we emphasize more about the inspirations from concluded action phases to creating tools.

These tables (Table 3.1, Table 3.2, Table 3.3) show the insights that result from the functionality decomposition. They will give support as inspirations for designing create tools of A3AO, which can help the users easily create the functionalities. Because the same category functionalities share similar creating actions in an abstract perspective from our analysis. For example, the summary category functionalities basically share the main actions of collect, translate/process, abstract, quantification, and present.

The concluded main action phases of each functionality type can be abstracted as tools to support creating A3AO and this part will be detailly introduced in section 5.5. These insight tools still should make adaptations for different functionalities. Because even in the same category, each functionality has its special usage. The diagrams show what these insight tools should adapt for.

**Table 3.1, Summarized category main action phases and specializations**

| Main phase | Stakeholders and system concerns | Top view | Parameters and system requirements | Physical view | N2 diagram |
|---|---|---|---|---|---|
| Collect | 1. Allowing for human-related material collection<br>2. Be dynamic for different communication tools | 3. Allowing for technical document and examples | 4. Adaptions for listing function | 5. Adaptions for large numbers of objects/actions | 6. Adaptions for logic relationship display |
| Translate/ process | 1. Be dynamic for different design tools | 2. Be dynamic for different discipline knowledge | | | |
| Abstract | | 1. Allowing for different information size | | | 2. Adaptions for inserting items |
| Quantification | | 1. Relationship between limitations and quantifications | | | |
| Present | | 1. Allowing for simplified display | | 2. Adaptions for different category difference | 3. Adaptions for diagram |

As is shown in Table 3.1, it is based on Summarize functionality decomposition. The main actions phases are Collect, Translate/process, Abstract, Quantification, and Present.

The main action phase works as the standard component, and it should support different functionalities specializations. For the collect phase, the generated tools should adapt for allowing human related materials, and be dynamic for different communication tools (interview, questionnaire and so on). When it adapts to Top view, it should allow for technical documents and examples. For Parameters, it should make adaptions for listing the functions. For physical view, it should adapt to a large number of objects and actions related to systems. For N2 diagram, it should adapt for showing logic relationships.

The Translate and process main phase related tools also have some specializations, For Stakeholder and system concerns, it should be dynamic for different design tools. For Top

view, it should be dynamic for different discipline knowledge.
The Abstract main phase related tools should allow for different information size and adapt for inserting items. The Quantification main phase related tools should show clearing about the relationships between limitations and quantifications. For the Present phase related tools, it should allow for simplified display (For Top view), and adapt for different category of physical perspective (For Physical view) and adapt for diagram displaying (For N2 diagram)

**Table 3.2, Expand category main action phases and specialization**

| Main phase | Functional view | Design decisions | N2 diagram |
|---|---|---|---|
| Listing | Allowing for listing items | | |
| Expand | 1. Expand from top level functions 2. Functions can be linked | 3. After expanding, there is still a combing process | share the components of summarize frame |
| Present | 1. allowing for net form present | | share the components of summarize frame |

Table 3.2 shows the expand functionalities based main phases and their specializations. The main action phases are Listing, Expand and Present.
For listing phase related tool, it should allow for listing items, For expand phase related tool, it should allow for expand from top level functions (Functional view), and functions can be linked. And it should remain a combing process (Design decisions) because when making design decisions after expanding the strategies there is still a process to combining them together to guide the design. For the present phase related tools, it should also allow for the net from presenting.

**Table 3.3, Evaluate category main action phases and specialization**

| Main phase | Fun key | Roadmap |
|---|---|---|
| Identify | | |
| Measurement/evaluate | 1. Allowing for the link of Function and key driver 2. Optimization for budget/tradeoff display | 3. Allowing for Logic relationship between past, current, and future |
| Repeat | 1. Take care of different hierarchical relationship | |
| Present | | |

Table 3.3 shows the evaluate category functionalities based main phases and their specializations. The main action phases are Identify, Measurement/evaluate, Repeat, and present.
For the Measurement/evaluate main phase related tool. It should allow for the link of functions and key drivers, and optimization for budget/ trade off display (Funkey) and allow for a logic relationship between past, current and future (Roadmap). For Repeat main phase related tool, it should take care of different hierarchical relationships.
All these analyses will give strong support for later design phase, in that part we will purpose the create tools to easily create the functionalities and visualize them based on all this chapter analysis results. But it should be noted that these are inspiration, some of them may be practical, some of them are not, the design will base on them but not be restricted by them. The visualization of create tools will also relate to these real useful content

# 4. Interaction frame

In this chapter, based on the stakeholder research output, we are going to build the interaction frame to guide the later interaction visualization. What makes it different from other interaction design is that this research part tries to use A3AO/systems engineering method to drive the process of building interaction frame.

## 4.1 Introduction to current interaction design method

Interaction design has become an important mediation between the digital devices and humanity with the development of electrification and information technology. The digital devices are more flexible, multiple, and complex in last decades. How to design qualified interaction is still a topic that attracts a lot of researchers and designers. There are three well known and evaluated interaction design mythologies in design discipline.

### User centered design

The first method that is widely use in current interaction design is User center design method, which is proven effective in practical industry development. In generally definition, User centered design is to evolve the Users into design process from the beginning to end and base on the User's requirements to guide the design solutions.
According to Abras, C., Maloney-Krichmar, D., & Preece, J. (2004), 'User-centered design' (UCD) is a broad term to describe design processes in which end-users influence how a design takes shape. It is both a broad philosophy and variety of methods. Their research emphasizes three main parts in User centered design: evolving the users, usability testing, and participatory design. There are several methods that can evolve users, interviews, questionnaires, focus groups, observation, diary, gaming and so on. Most methods in evolving the users at the beginning part of design is to get the requirements of the users. According to Dumas & Redish (1993), the second part – usability testing is to achieve five goals： improve the product's usability; involve real users in the testing; give the users real tasks to accomplish; enable testers to observe and record the actions of the participants; enable testers analyze the data obtained and make changes accordingly. Generally concluded, the usability testing is to let the users help to evaluate the designed product usability, it focusses on involving users to improve evaluation of design. The third part, participatory design, also called co-design in some research, is trying to involve the users in design phase. In general design process, after getting user requirements, the designers are the key to conduct design. But in participatory design, the users can join the design procedure and share their ideas. To some extent, this kind of participatory design can approve users to intervene design phase more

directly.
The User centered design also has its limitations, in a lot of practical industry cases, the users are not the only stakeholder. Only focusing on users but do not pay enough attention to other stakeholders would lead to a biased or of weaknesses design output in complex usage backgrounds. The second limitation is that the involved users can become an uncertain variable. Who are invited, how the users are involved should be always considered carefully when doing User centered design. The third limitation is about the participatory design, to involve the users in design phase is a risky choice, the chosen users can influence the design outcome too deeply, and the meaning of designer's professional ability and skills do not get fully leased. The users are not designers and cannot guide the design fully in the design phase. The use of participatory design should be careful. However, the User centered design has limitations but still give supports on the fact doing deeply user research and get user requirements are important in interaction design. The user research based design but not user centered design could a trend in later design method development and research.

## Scenarios based design

Scenario based design is also a kind of interaction design method. Its characteristics are that using scenarios to drive the design development. Scenario based design method can play important role when lack of user participation or the involved users are not enough to support all design procedure, or the backgrounds of design are complex, and the stakeholders are hard to be involved. In the cases above, the scenarios can help to simulate the stakeholders (including users) scenarios of problems before design, scenarios of usage, scenarios of after using problems and so on. These scenarios can support the design development and help the designers to make judgement.
According to Anggreeni, I., & van der Voort, M. (2007), there are seven kinds of scenarios in product development: Explorative scenarios, Actual practice scenarios, Future practice scenarios, Possible problems scenarios, Interaction scenarios, Detailed interaction scenarios, Validation scenarios. The use of scenarios is flexible and could be adjusted according to the practical design cases.
The core of scenarios design is using the scenarios to simulate different stages of design procedure. These simulations could help cover the blind areas that the user research or practical experiments can not reach. There are also some problems of scenarios based design, such as the quality of scenarios has requirements on designers' ability and experience, and the scenarios could not fully take the place of stakeholder research, it is more like a derived assistant design tool to help the design development. It should be noted that the use of scenarios based design should be considerably flexible, and the use of scenarios should be always closely linked to the actual product (interaction design) development situations.

## Cognition based design

There is a design approach and school thought that is based on humanity psychology study and cognition related study, it is called tangible interaction by some researchers. According to Sutton, 2006; Dourish, 2001, tangible user interfaces have been a fruitful subject for discussions on the nature of embodied cognition; that is the notion that cognition happens not just within the limits of our mind/brain but is readily supported and replaced by elements around us in a fluid fashion. According to Van Gennip, D., Orth, D., Imtiaz, M. A., van den Hoven, E., & Plimmer, B. (2016, November), they note the attraction of tangible interfaces based on human cognitions, 'What our mind is willing to accept and rely on as a cognitive scaffold remains a hot topic for discussion in both cognitive philosophy and the HCI community. Tangible interfaces are where physicality, embodiment, and cognition meet, hopefully unlocking possibilities for effective and enjoyable systems beyond the digital interfaces so commonly seen today.' As is mentioned by Kirsh, D. (2013), 'The theory of embodied cognition offers us new ways to think about bodies, mind, and technology.' According to Maher, M. L., Gero, J., Lee, L., Yu, R., & Clausner, T. (2016, July), they emphasize the benefits of tangible interaction design and its relationship with the physical world, 'Tangible interaction takes advantage of how people typically interact with physical objects in the world and brings those affordances to interactions with digital environments.'

The cognition based interaction design or called tangible interaction design relies on transferring or applying new findings of human psychology and cognition studies into interaction design discipline. Currently the main application cases of tangible interaction are experience equipment, digital arts, game design, augmented reality and so on. The cognition based interaction design has its advantages to bring new feelings in sensory experiences and added pleasure. It also has its limitations of focusing too much on sensory, cognition feelings, but not focusing on solving the practical problems in complex situations. It can be suggested as an assistant design method to improve the design outputs' experiences of sensory and cognition feelings.

## 4.2 Apply A3AO/systems engineering to interaction design

The current interaction design methods try to develop the interaction design from user, scenarios, cognition perspectives. They are effective in some cases and deserve to be considered as methodological references. However, in our case, the A3AO interaction involves multiple stakeholders, involves several complex scenarios, and has high requirements on organizing large number of functions. The traditional interaction design methods are hard to cope with this case. It deserves to be noted that the systems engineering is well suited to the complex design situation. And the total interaction can also be regarded as a complex system. There are some possibilities to introduce A3AO/systems engineering to interaction design discipline.

If we try to use systems engineering, it is needed to define and make sure the procedure of application. Interaction design still has requirements on the stakeholder research and visualization. When and where the systems architecting should be placed should be considered. *The developed interaction system can be defined as a set of interactive functions and operations that can guide creating usable visualizations under design that meets the requirements of stakeholders.* The systems architecting focuses on functions and operation actions inside the interaction system.

In our research, the A3AO/systems engineering method is applied to the interaction design discipline, and the total interaction can be regarded as a system and based by functions. The stakeholders research is the input before systems architecting. The interaction frame is the output after systems architecting and composed by functions and operation actions. Then the interaction frame could guide the visualization. The total process can be seen in Figure 4.1.

In this research, the system architecting of the interaction system includes the use of top view, adapting top view and stakeholders' problems to get main functions, expanding main functions and top view to detailed functions and operation actions.

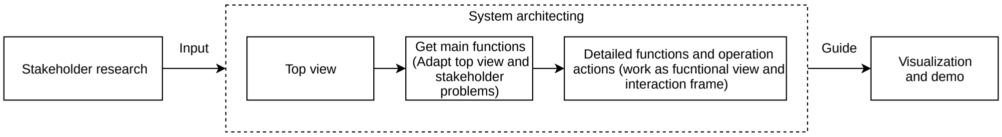



**Figure 4.1, Using system architecting in interaction system**

## 4.3 Top view of the A3AO manipulate center

The Figure 4.2 below shows the top view of the A3AO use, the upper part is the top view, the lower part is the documental process view. As is analyzed in the Section 1.4.1.2, the document- driven working process is used by several high tech companies.

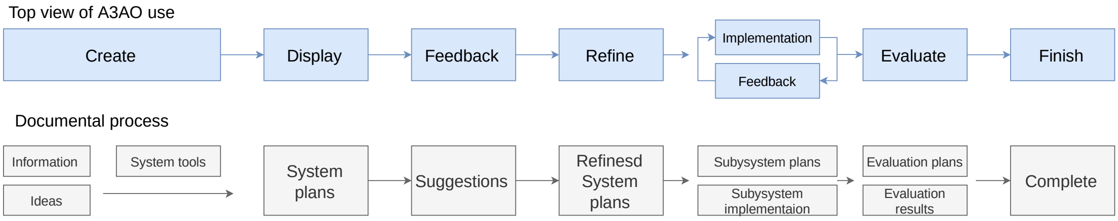



**Figure 4.2. Top view of A3AO use and Documental process**

The top view of A3AO use can be concluded as Create (the A3AO documents), Display (the A3AO documents), Feedback (from the systems engineers/subsystem engineers/outside stakeholders from development group), Refine (the A3AO documents), Execution (implementation of systems plans and subsystem plans) and Feedback (for subsystem plans), Evaluate, Finish.

The documental process, which is related to Top views, starts with the information and ideas, processed by system tools and analysis, generates system plans. After getting feedbacks, we get suggestions for the system plan. Then we refine the systems plans and the subsystem engineers will create the subsystems plans. After getting feedback from systems engineers, the systems engineers will implement the subsystems. Then, it follows with the evaluate plans and we can get evaluate results after implement the evaluate plans. Then the process is done.

It can be answered that what kind of interaction that we are going to create according to the top view analysis and the front stakeholders' research. It is also related to the two main research questions. So, we purpose the design goal of this A3AO interaction system. It has 3 main goals.

The Design goal:
*1. Adapt the A3AO interaction to large screen devices*
*2. Solve the problems from stakeholder's research*
*3. Create full circle using experience of A3AO*
The following design will adapt to these goals.

## 4.4 Get main functions

This part is to generate the main functions. The method of generating is adapting the top views and stakeholder requirements, to propose possible solutions. Then according to possible solutions, we can get main functions of the interaction system.
As is shown in the Figure 4.3, the Top view, Stakeholder problems, Possible solutions, Main functions are listed. In fact, it is a logical inference from Top view and Stakeholder problems to solutions and main functions. The main functions will guide the later generation and iteration of detailed functions in these A3AO interactions.

### 4.4.1 Adapt stakeholders' problems to the top views

In the stakeholders' research, we get nine main problems. In this step, we relocate these problems into different phases of the top view. Some problems can happen in a lot of phases. According to this approach, we can easily see what the problems are in each top view phase. The detail of the adaptation can be clearly seen in the Figure 4.3, the first and second vertical line are Adapting Top view and stakeholder problems.

### 4.4.2 Give possible solutions for problems

According to the problems in each phase of top view, we can try to ideate possible solutions for the problems. As is shown in Figure 4.3.
In the stage of Create A3AO, For the problem of "The system plan is not mature and brings repetitive work and low efficiency.", we can try to get possible solutions as "suggestions on system building (good examples, considerations) / listen to feedbacks put time on refining decisions." For the problems of "The requirement changes from the outside stakeholders", the possible solution is "Space for stakeholders extra requirements/refine requirements/ delete requirements".
In the stage of Display A3AO, For the problems of "The subsystem engineer has problems in understanding system requirements." And "Different disciplines engineers have problems in communication because of jargons.", the possible solution could be

“Provide explanations
- what the design goal, bolded or high light them
- how system requirement related to their own disciplines
(highlight related part about their disciplines)
- how to achieve it (give suggestions)
- how to deal with the jargons”
For the problems of “Different disciplines engineers have different preferences of information transfer.” The possible solution could be “Change display preference”
In the stage o Feedback of A3AO, For the problems of “The subsystem engineer has problems in understanding system requirements.” And “Different disciplines engineers have problems in communication because of jargons.” The solution could be
“Help the systems engineers and subsystem engineers find, note, and send the problems
- how to quick locate the problems
- how to clearly write”
The details of possible solutions in each phase are clearly shown in the Figure 4.3. The possible solution vertical line of the figure displays ideation from problems to possible solutions.

### 4.4.3 Conclude and generate related main functions of interaction

The main functions should be a kind of activity inside the interaction that related to the possible solutions and can solve the stakeholders' problems. The interaction components are carriers of interaction components
There are two ways of generating the main functions of the interaction. The first one is to generate from the top view steps. Like create step, the main function should be to provide tools that help to create A3AO, the create toolbox is the interaction component to achieve the functions. And according to documental process in Figure 4.2, a function that can manage the A3AO documents should also be generated.
The second one to generate main functions is to conclude the possible solutions ideations. Then concluding interaction components from the main functions are possible. For example, the ideation “suggestions on system building (good examples, considerations) / listen to feedbacks put time on refining decisions”, can generate the main function “to provide suggestions.”

Seven main functions are concluded according to ideation of possible solutions and top view. They are the items below:

***To help to create A3AO***
***To provide suggestions***
***To easy edit and update stakeholders' requirements***
***To provide explanations to support readers' reading***
***To help adjust display preference***
***To feedback and respond***

***To manage documents***

These main functions will be achieved by interaction components. The interaction components are ***Create/edit toolbox, Suggestion helper, Explanation lab, Display toolbox, Feedback channel, Document center***. The document center is generated from the main function "to manage documents". They are shown in the Figure 4.3 the forth vertical line. There by are the definitions of these interaction components.

***Create/edit toolbox:*** A toolbox collection for creating and editing A3AO.
***Suggestion helper:*** Give possible suggestions when SEs create A3AO to help them do a more mature systems design.
***Stakeholder requirements:*** To give lasted stakeholders requirements, and edit them
***Explanation Lab:*** To provide related explanation about the content inside functionalities, the explanations can come from the A3AO itself, can also from the knowledge lab or internet.
***Display toolbox:*** To help the readers easily read the A3AO and change their display preference.
***Feedback channel:*** To give feedback, review feedbacks, replay feedbacks.
***Document center:*** To choose the document to open and show the status and information of the document.

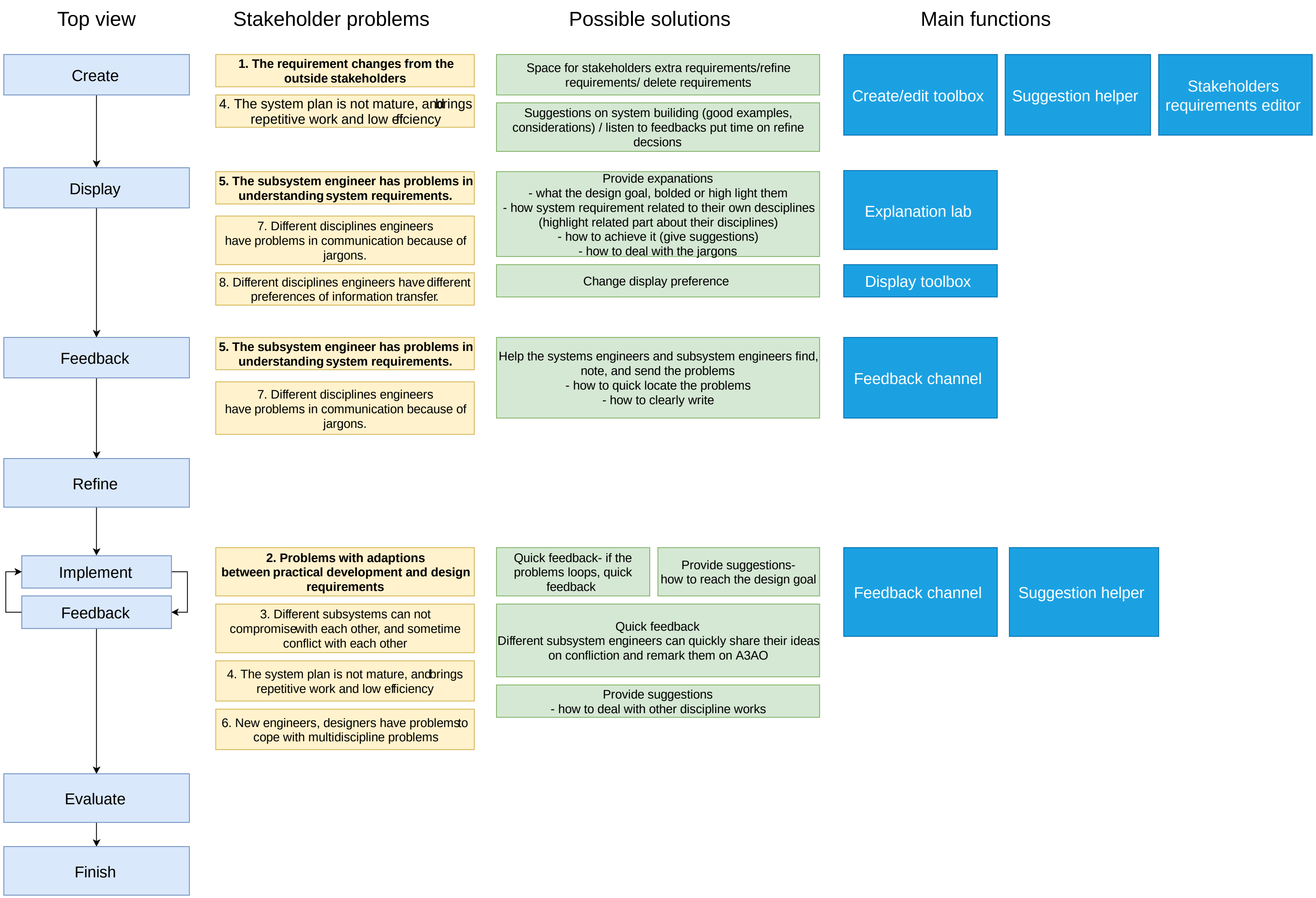



Figure 4.3, Top view to Main functions of interaction

## 4.5 Expand the main functions subsystems to detail functional view

In this phase, we already have the top view of the interaction and main functions and related interaction components. In this section, we combine the top view and interaction components together to expand the detail functions and related activity inside the interaction frame. The information is in the Figure 4.6.

### 4.5.1 Main actors(users) groups

There are three main actors in the interaction frame, Systems engineer, Subsystems engineer and Outside stakeholders. And they are also main estimated users for A3AO interaction. Each function and activity have its related main actor groups. In the interaction frame, this information is shown by front loaded blocks before each detail function block. Some detailed functions and activities will face multiple users. The front loaded blocks are in Figure 4.4. It is also shown in Figure 4.6.

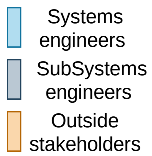



**Figure 4.4, Main actors (users) groups**

### 4.5.2 Adapting main interaction components and top view

In Figure 4.6, in the vertical view, the top view steps are set on the left, in the horizontal view at the top line, the main interaction components are unfolded in order. And we can expand the detailed functions and activities by combining the related top view phase and main function and related interaction components.

For the example of “Create” top view phase and “Create/edit toolbox” main function, the detail functions are generated as light blue blocks, the example is shown in Figure 4.5.

Collect/input materials

Choose functionalities

Show relevant tools

Edit.

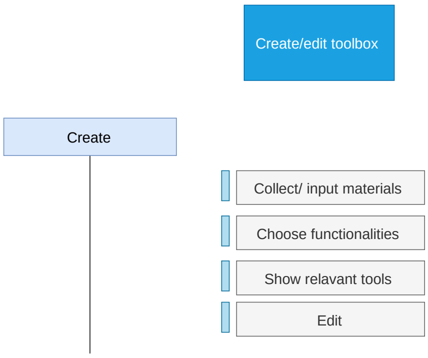



**Figure 4.5, An example of adapt interaction components and top view**

By this method, each step of detailed functions/activities is well expanded and organized in order. The detailed information can be seen in the interaction frame diagram, and it plays similar role of functional view. The order of the functions follows the top view organizations. This interaction frame diagram can clearly show what kind of interaction frame that we need from a functional view. It can strongly guide the later design and be useful for interaction designers to do visualization planning.

### 4.5.3 Get interaction frame

By interaction frame, as is shown in Figure 4.6, we can see the internal relationship between the detail functions and activities by the guidance of top view and main interaction components. The top view also plays a role of timeline to make functions in chronological order. The main functions related interaction components can display the detailed functions/activities collections in vertical vision. This interaction frame will strongly support the later design.

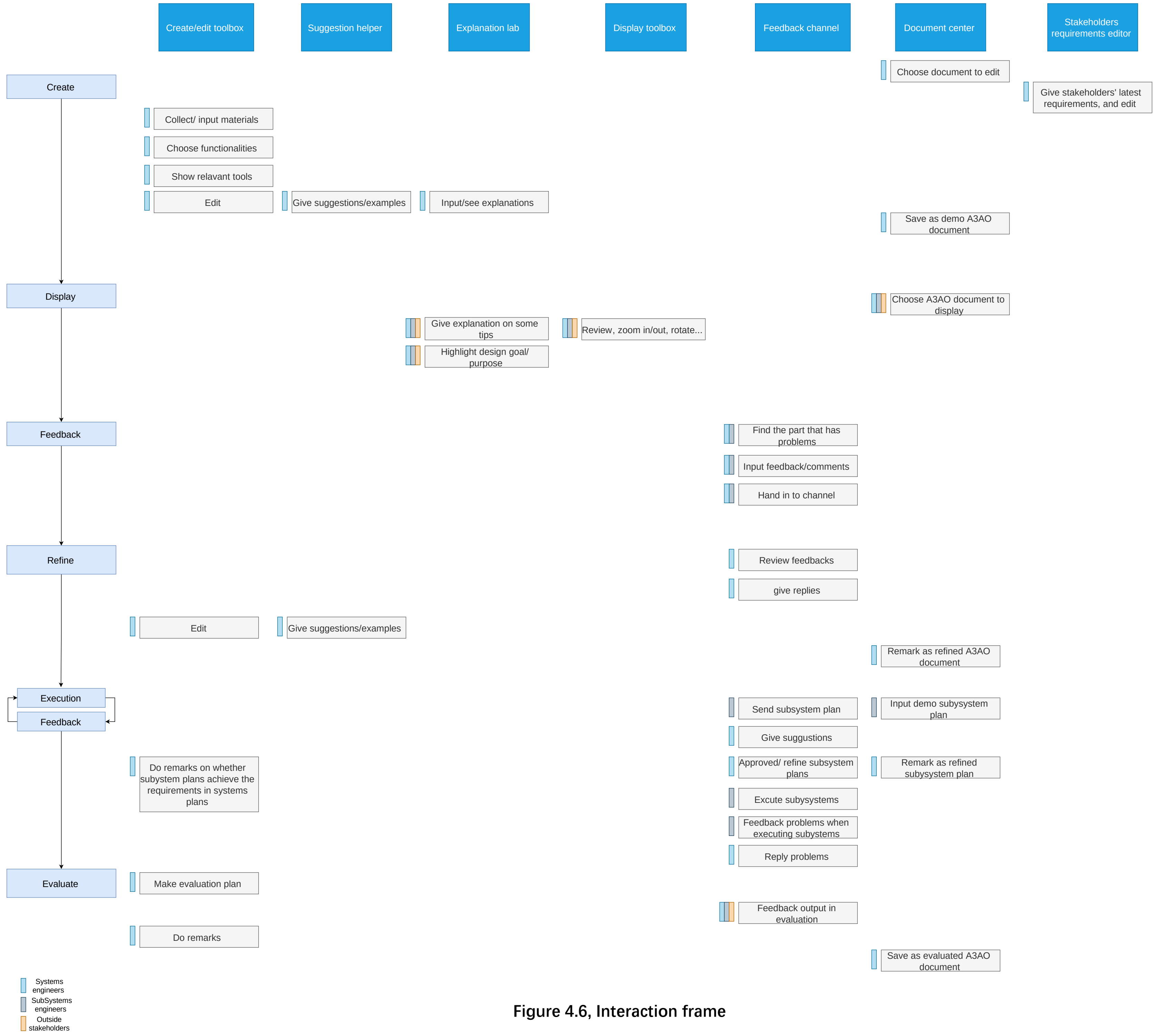



Figure 4.6, Interaction frame

# 4.6 Design strategies

## 4.6.1 Considering focusing more on A3AO

This interaction should both consider the stakeholder requirements and A3AO files' properties. The evaluate part in the top view is summarized according to the working process of the Section 1.4.1.2. However, the evaluate phase is not strongly related to A3AO defined usage stages. In stakeholder research, the developers will use several tools and technical documents to support the evaluation, they are important but not relate to tightly with the top-down system design method, which is A3AO main estimated domain. And how to connect the complex evaluating tools to this interaction is also an obstacle. Too complex functions will increase obstruction for later design organization. So, the design decision is made to remain the three main parts of the Top view and their related stages- create, display and feedback. They can cover most using scenarios related to A3AO and can work as an effective using circle of the A3AO documents. The remained stages are shown in the Figure 4.7.

The following design will concentrate on these three stages and do more work about interaction and visualizations.

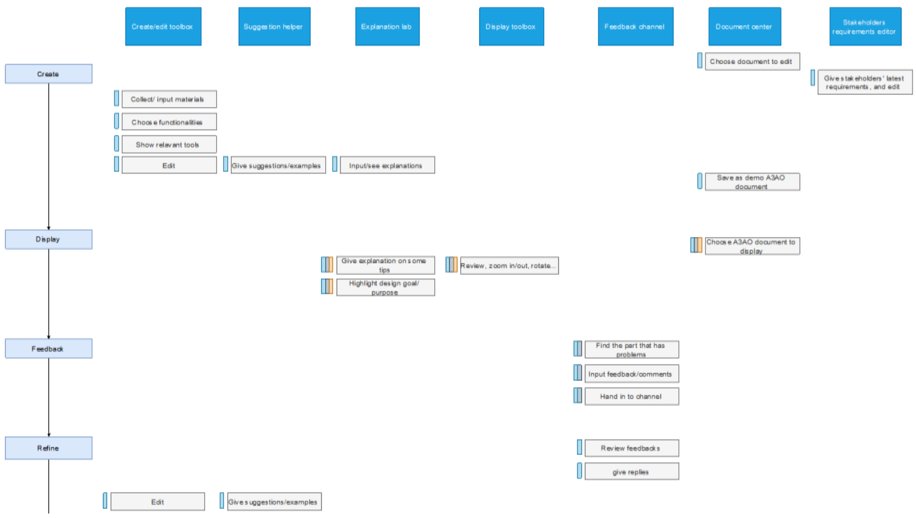



**Figure 4.7, Remained stages**

## 4.6.2 To specify main functions and detail functions

In the top view analysis phase and interaction frame, main functions and related interaction components are concluded: ***create/edit toolbox, suggestion helper, stakeholder requirements, explanation lab, display toolbox, feedback channel, document center***. They are collections of a series of detailed functions and activities. In later design phase, it is needed to visualize these interaction components and create proper interaction to achieve these main functions and related detail activities.

# 5 Design and demo

In this chapter, we will comprehensively use the analysis results to do design. It includes visualization of interaction frame, and main interaction components, the design for create tools which is used for creating and editing A3AO documents. After that, we will develop a demo on large screen devices.

## 5.1 Input of interaction frame

Top view and documental view (From Section 4.3)
Main functions (From Section 4.4)
Three stages of usage: Create, Display, Feedback (From Section 4.6)
Three stakeholders' groups: Systems engineers, Subsystems engineers, Outside stakeholders
Detail functions and activities (From section 4.5)
Design goal (From Section 4.3)

## 5.2. Ideation

### 5.2.1 Plan 1 of integrated

As is shown in the Figure 5.1, this design ideation tries to integrate all detail functions and interaction components into one operate page, it is to some extent similar to Photoshop interfaces, which is trying to be compact in limited space.

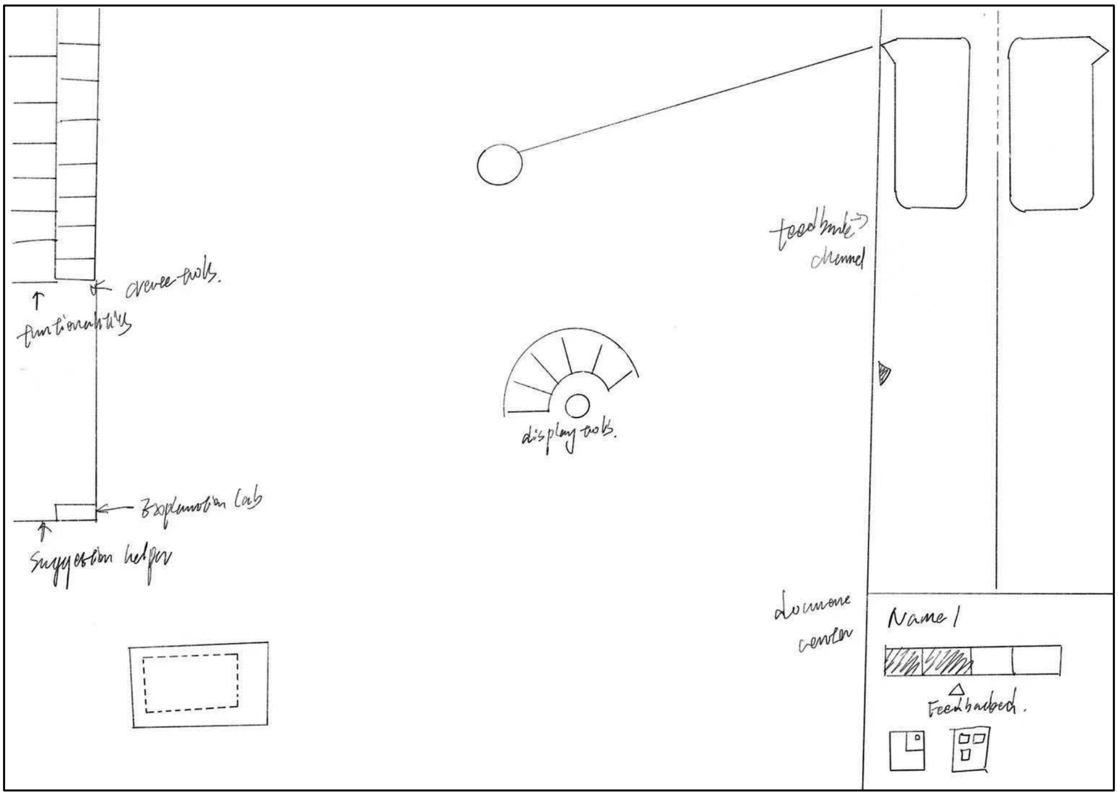


Figure 5.1, Sketch of Plan 1 of integrated

## 5.2.2 Plan 2 of different modes

This design plan follows the top view of the A3AO interaction, according to the main usage stages of the A3AO. The interaction is composed of a menu page and three modes: create/edit mode, display review mode, feedback mode. There we can see the ideations of these designs. The sketch of ideation can be shown in Figure 5.2, Figure 5.3, and Figure 5.4.

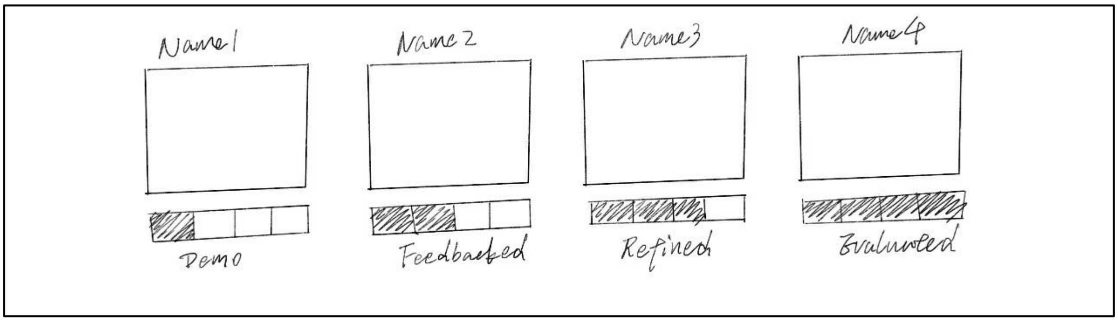



Figure 5.2, Sketch of Plan 2 document center

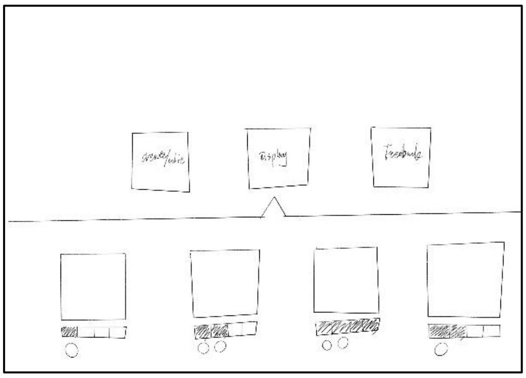


Figure 5.3, Sketch of Plan 2 choosing modes

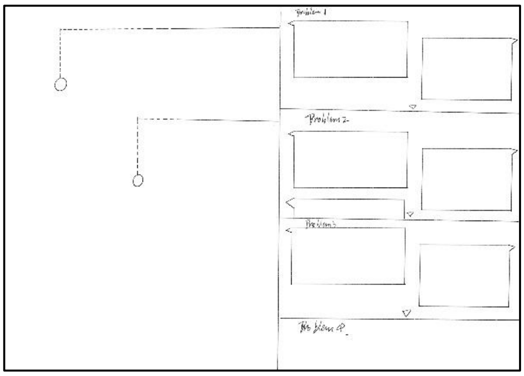


Figure 5.4, Sketch of Plan 2 feedback channel

In the document center, the status of each document is stated, and the creator and reviewers are also shown. The three modes entrances are set in the menu page, and the ***document center***, one of the main interaction components is in the down part of the entrances. The detail ideation picture is shown in Figure 5.5,

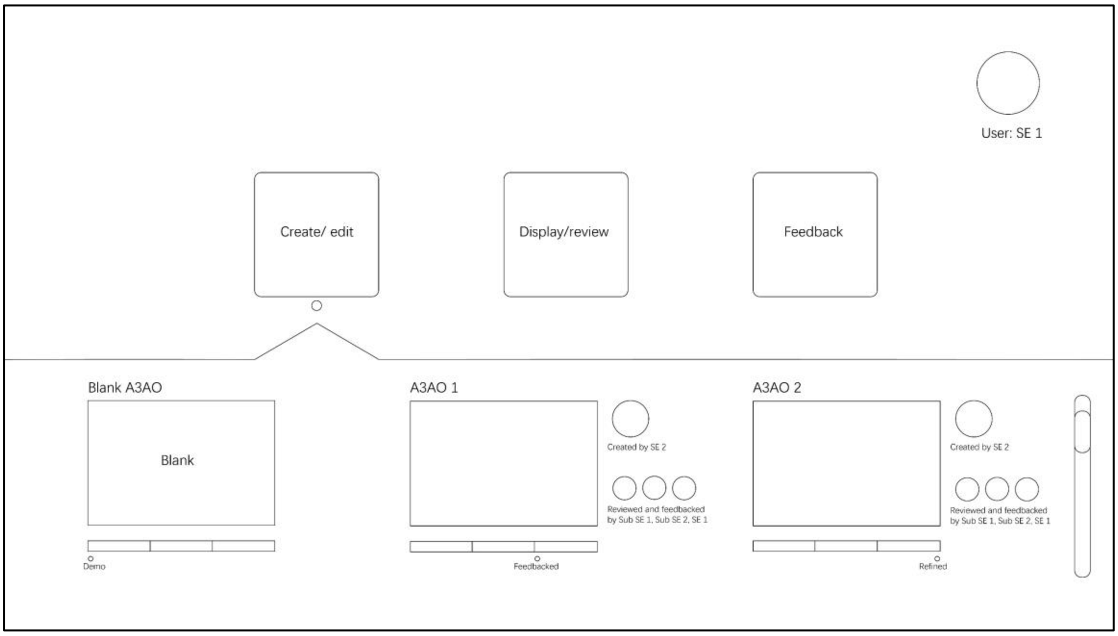



Figure 5.5, Specification of Plan 2 menu page

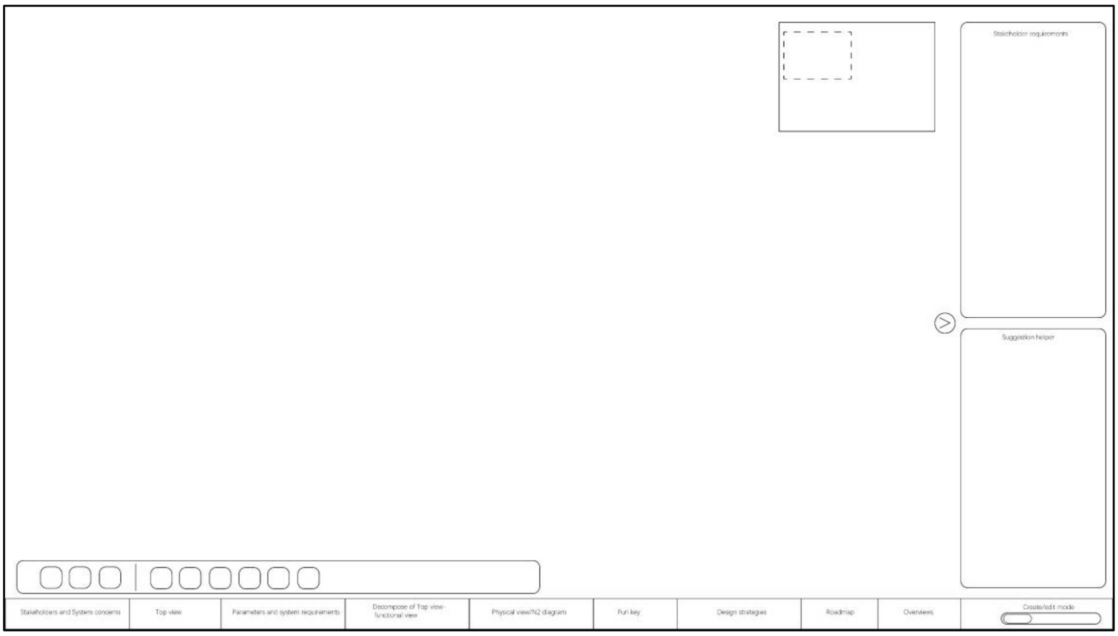



**Figure 5.6, Specification of Plan 2 create mode**

The create mode page is shown in Figure 5.6. The functionalities bar is in the down part of the page, and users can choose what kind of functionalities that they want to create. On the upper part is the ***Create/edit toolbox***, which is one of main interaction components. The create toolbox is composed of fixed tools and assistant tools. The details of these tools will be introduced later.

The side bars are ***Stakeholder requirements*** bar and ***Suggestion helper*** bar. The stakeholder requirements bar is designed to provide convenience for creators to easily add, delete, modify (outside) stakeholder requirements. The suggestion helper can provide useful information to help creators easily build the systems. Both two of them can be hidden to give more space for reading and creating.

The window on the left corner is a preview window, which is designed to help users always be aware of the location in the document and will not lost their position.

There is a menu button on the right down corner, which the user can do some settings or go back to menu page. There is a slide bar on also on right down corner, which the user can easily slide into other modes.

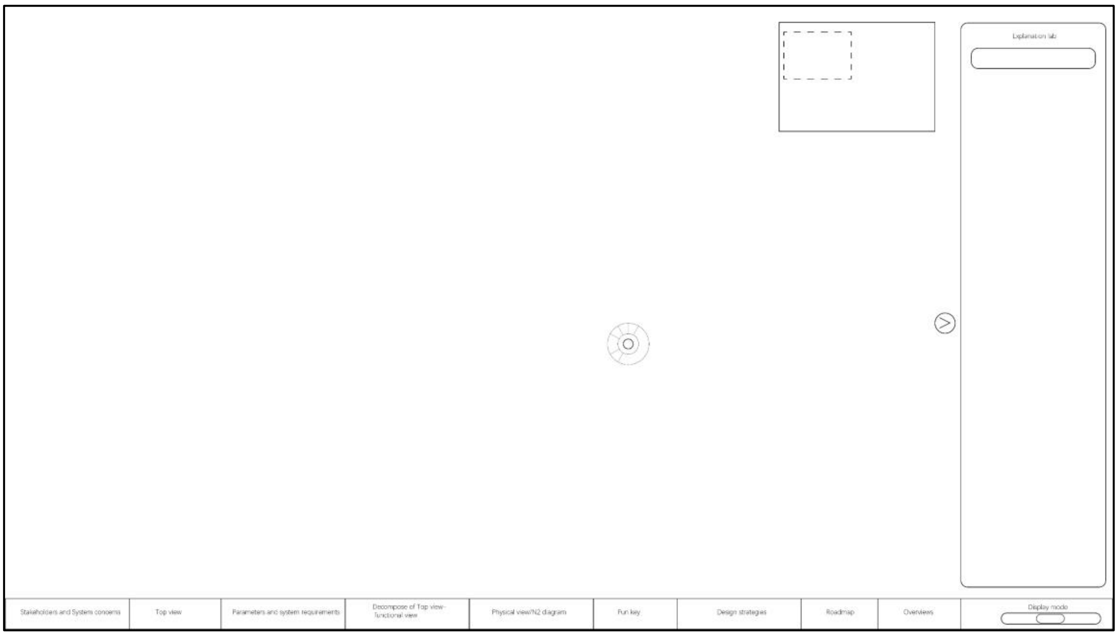



**Figure 5.7, Specification of Plan 2 create mode**

As is shown in Figure 5.7, The display/review mode has a similar layout to the create mode. The functionality bar here plays a role of quick reviewing. Once the user chooses one functionality, the display area will automatically zoom in into that part.

There is a ***display tools*** circle which can move and set according to users' willing, it is a collection of different display tools, such as zoom in, zoom out, show pictures only and so on, On the side bar, it is ***explanation lab***, which provides explanations to the certain part of A3AO, user can choose to seek information from A3AO following pages or seek information from the internet. The search bar is also inserted in this center. Of course, this part can also be hidden.

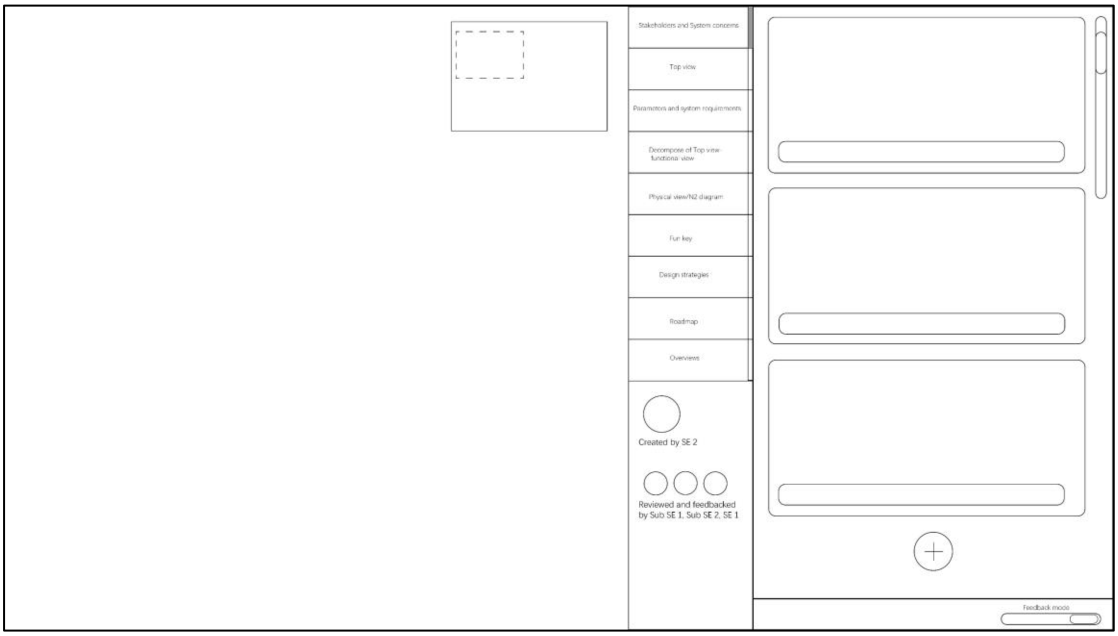



**Figure 5.8, Specification of Plan 2 display/review mode**

The feedback mode has a different layout. As is shown in the Figure 5.8, The reading space is

narrowed, and more spaces are prepared for the ***feedback channel*** on the right. The functionality bar still exists but shown as a vertical view, which is more adapted with the feedback channel. A user dashboard is also provided to show the creators and reviewers of the document. The feedback channel is composed of standard bubbles and the content of feedbacks is inserted. In each bubble, the user can also reply to the content. The add button can provide a new bubble for feedbacks.
On the right down corner, the slide bar remains in the same position.

## 5.3 Design plan choosing

The plan 1, is much more a traditional professional tools interface design and tries to integrate all interaction components, detailed functions into one operation page. This crowded layout is common on PC based engineering software that uses a keyboard and mouse as input devices. However, the A3AO interaction is targeted as large screen devices, the PC and touchscreens are both considered, there could be problems for plan 1:
1. Too many interaction component are integrated crowdedly, the visual pressure of recognizing and using these components could be overloaded.
2. The small components icons and crowded layout are not friendly for touch screen users.
3. In fact, the plan 1 is more suitable for just creating the A3AO, but for the users who just want to read or give feedbacks the layout is not friendly.
4. Too crowded components will increase learning cost.

The second plan is chosen because it is more suitable for touch screen devices and its using logic is also more clear to cover the full usage of Create, Display and Feedback.
The highlights of plan 2 are:
1. The design of 3 modes avoid too many functions on one page, provide more space for the vision of reading, and a quick switch between modes is easy to operate. The user can quick choose which kind of usage stage that he wants to use.
2. A3AO Functionalities drive all modes, the A3AO documents are created by functionalities, the A3AO documents are displayed according to functionalities, the A3AO documents can get feedback according to functionalities
3. The interaction provides easy zoom in when choosing functionalities. And it is both friendly for PC and touch screen devices.
4. A lot of interaction components can be hidden to give enough spaces to read or edit.
5. Not crowded interaction components provide convenience for touch screen devices.

## 5.4 Design visualization

Based on the ideation, we visualize the interface in detail.

### *Menu page*

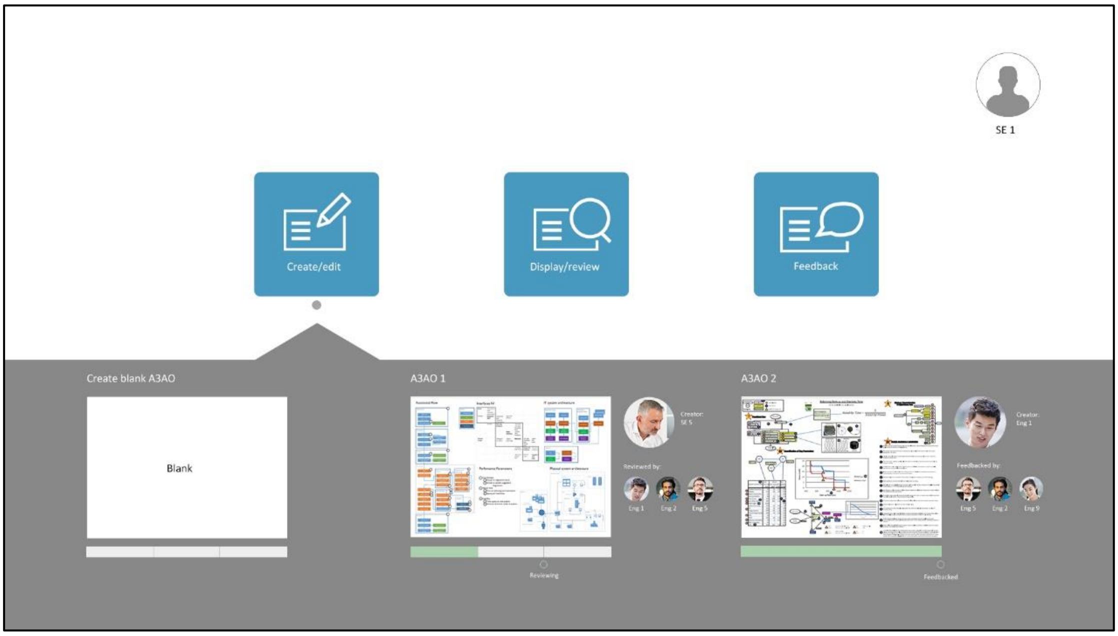



Figure 5.9, Interface of menu page

### *Create mode*

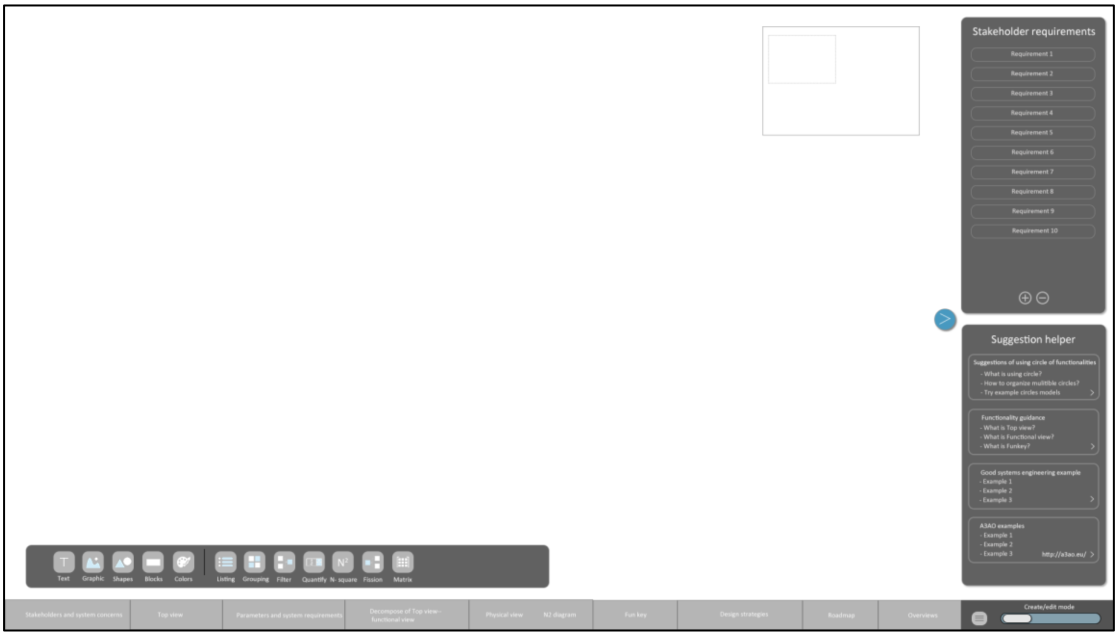



Figure 5.10, Interface of create page

### *Display mode*

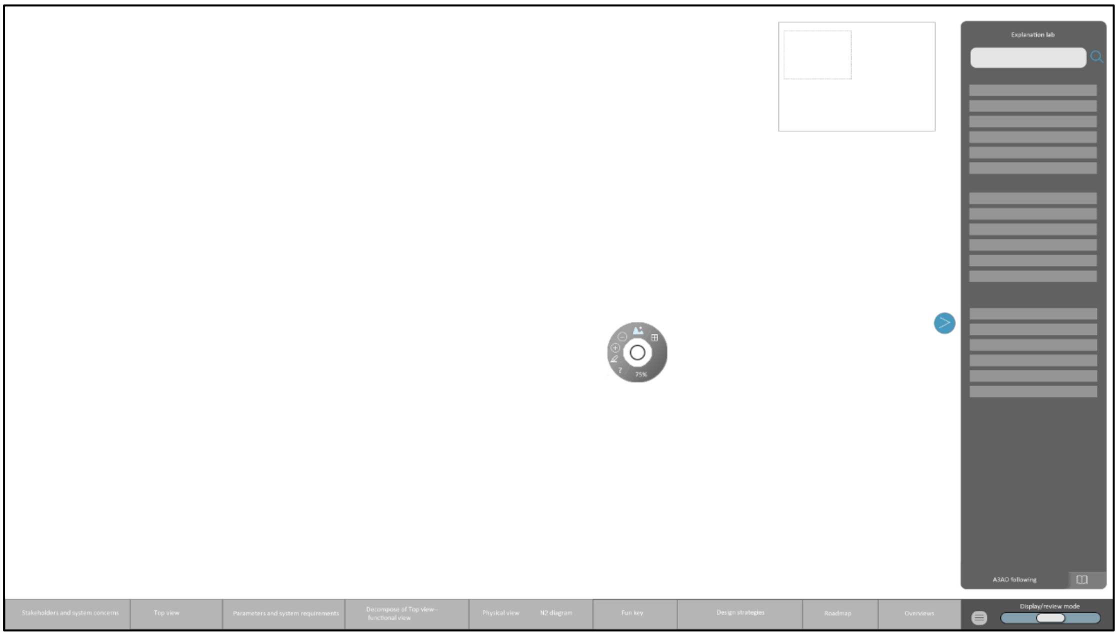



Figure 5.11, Interface of display page

### *Feedback mode*

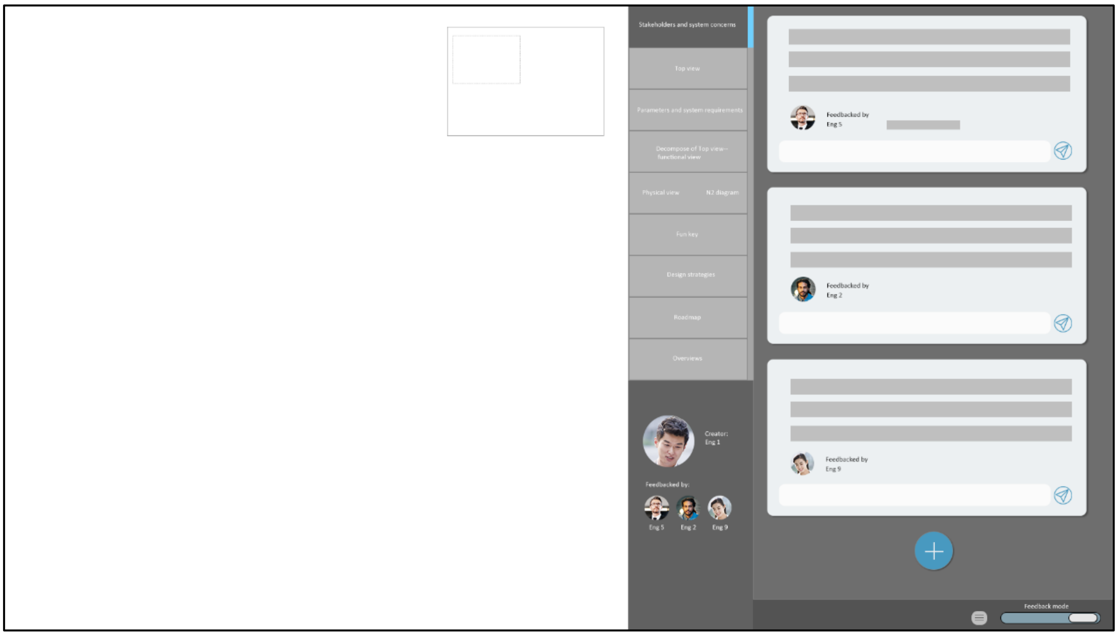



Figure 5.12, Interface of feedback page

### *Description of the interfaces*

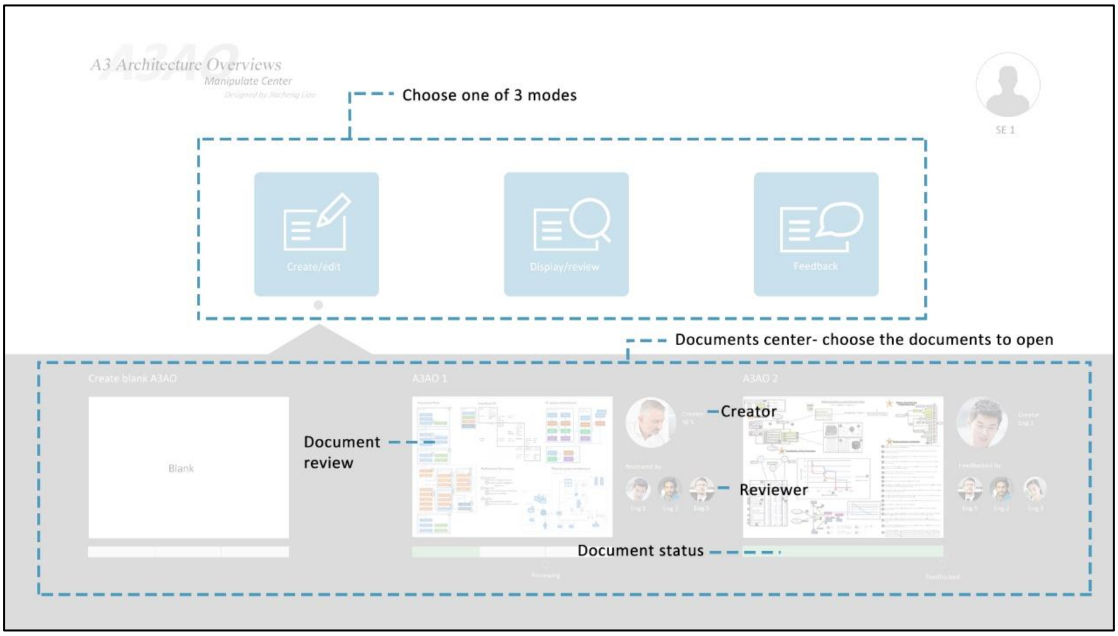



Figure 5.13, Interface of menu page description

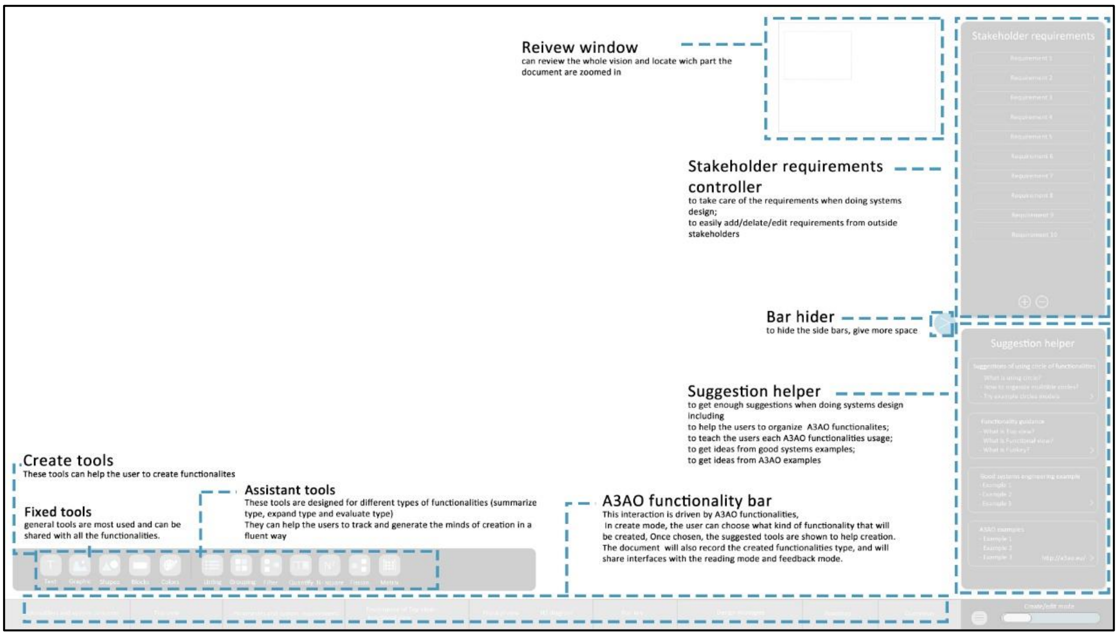



Figure 5.14, Interface of create page description

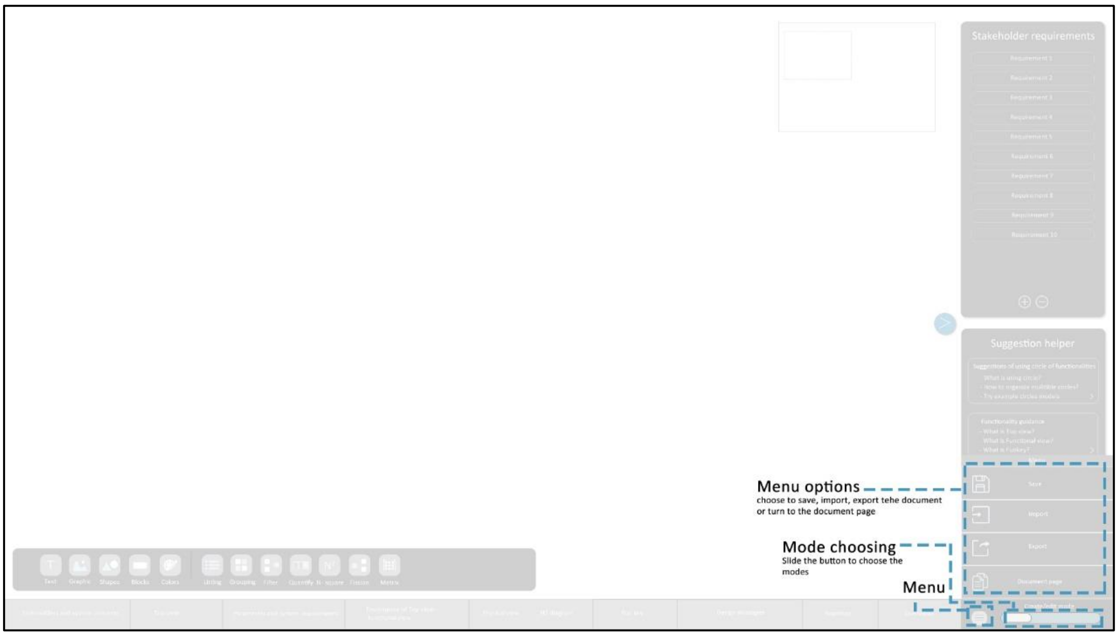



Figure 5.15, Interface of create page description 2

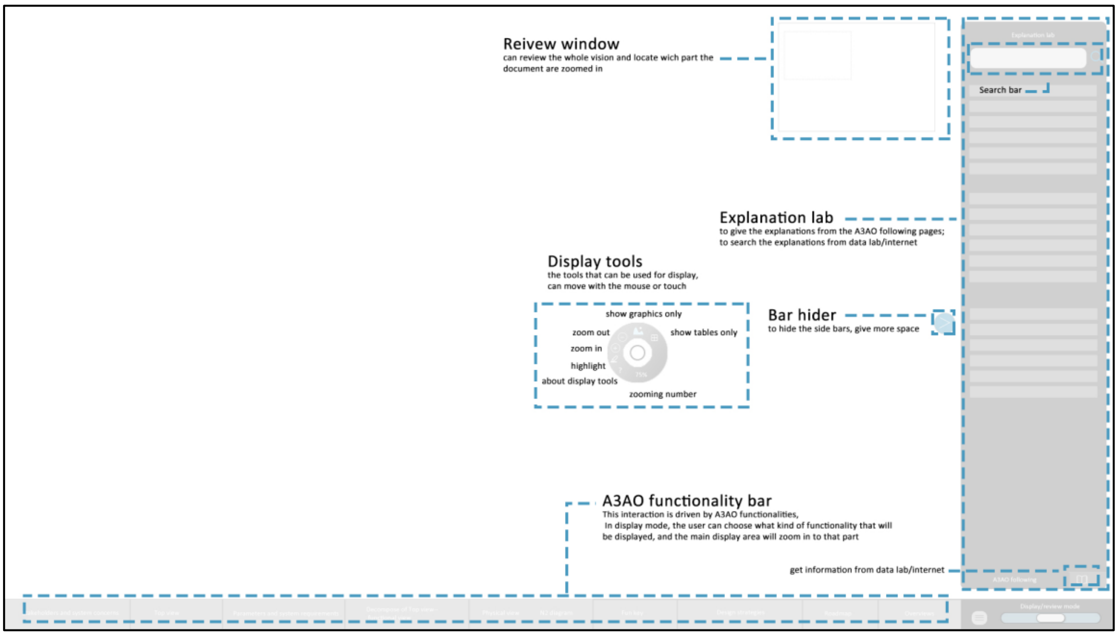



Figure 5.16, Interface of display page description

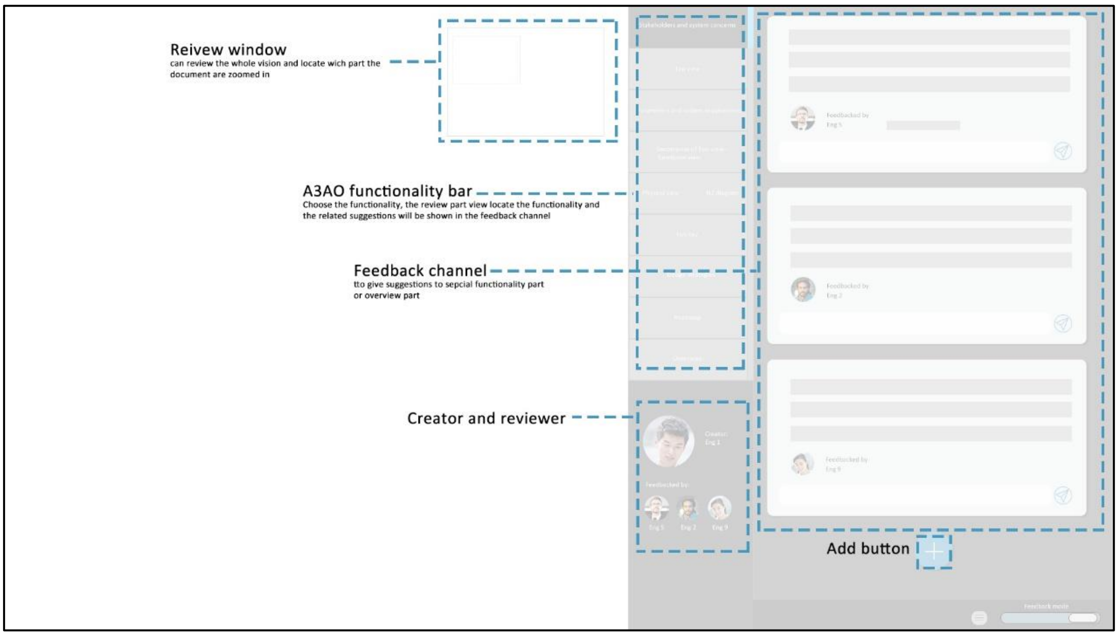



**Figure 5.17, Interface of feedback page description**

# 5.5 Create tools description

In create mode, we can use the create toolbox to easily create the functionalities, and these tools are based on the results of chapter platform design and functionality decomposition, which gives us a lot of inspiration about the main action phases of using functionalities.

## 5.5.1 From action main phases and inspiration to create tools

As is mentioned in the Chapter 3 platform design, We build the create tools based on the main action phases of functionalities and these tools will be the platform to create A3AO documents.

The main action phases for Summarize functionalities： ***Collect, Translate/Process, Abstract, Quantification, Present.***

The main action phases for Expand functionalities: ***Listing, Expand, Present.***

The main action phases for Evaluate functionalities: ***Identify, Measurement, Repeat, Present***.

We get inspiration from the main action phases and some of them could be directly transferred to create tools.

## 5.5.2 Description of create tools

The creating tools have two categories, the fixed tools and assistant tools. Fixed tools can provide basic components like text, graphic, block and shapes. The assistant tools are designed according to the main action phases of using functionalities, they could be useful for designing special functionalities. The aim of the assistant tools is to help the users to track and assist their thinking and minds. When creating these assistant tools, the theory of using loop of functionalities, to summarize, to expand and to evaluate, also plays important role on give suggestions that which kind of assistant tools could be useful when creating functionalities. The use of create tools are flexible and the platform both give suggestions and enough spaces of choosing which combinations of create tools

**Fixed tools**:
***Text，Graphic , Blocks, Shapes, Colors***
These tools are basic
***Text:*** input text, adjust the style of text
***Graphic:*** import the graphic, adjust the graphic
***Shapes:*** create the shapes, adjust blocks and shapes.
***Blocks:*** create the blocks, adjust blocks, link the blocks.
***Colors:*** adjust colors.

**Assistant tools:**
- Summarize functionalities: ***Listing tool*** (listing items), ***Grouping tool*** (grouping items), ***Filter tool*** (abstract items), ***Quantify tool***, ***Diagram tools*** (N2)

These tools are generated from the functionality decompose inspirations. Most of them are concluded and designed according to the main phases of using the functionalities, which are concluded as *Collect, Translate, Abstract, Quantify* and *Present*. The *Collect* is the inspiration of *Listing tools*, they are all about list and collect current materials to support later work. *Abstract* gives inspiration for the *Grouping tool* and *Filter tool*, the *Grouping tool* is a preparation stage between *Listing tool* and *Filter tool*. The *Filter tool* directly relates to *Abstract* action phase, is to summarize information into items we need. The *Diagram tool* is especially designed for the N2 diagram.
For the summarize functionalities, these tools are designed and the descriptions are in below:

***Listing tool:*** To list, input the information, items, ideas, minds and graphics
***Grouping too***l: To group information, items, ideas, minds and graphics
***Filter tool:*** To filter and summarized the information, items, ideas ,minds and graphics.
***Quantify tool:*** the specify and limit items from a quantification view.
***Diagram tool:*** To easily create the diagrams, especially for N2 diagram.

- Expand functionalities: ***Listing tool***, ***Fission tool*** (expanding items), ***Diagram tools*** (N2)

These tools are designed according to the main action phases of the expand categories functionalities: *Listing*, *Expand* and *Present*. The *Listing* tool is directly related to *Listing* main action phase and plays similar role of *Collect* main action phase, is to list and input information. The *Expand tool* and *Expand* main action phase is also has strong connect, they both focus on expand minds and items. the *Listing tool* and *Diagram tool* are also used in summarize functionalities.

***Listing tool:*** To list, input the information, items, ideas, minds and graphics.
***Expand tool:*** To expand the current ideas, items, graphic into more ideas, items, graphics

***Diagram tool:*** To easily create the diagrams, especially for N2 diagram.

-Evaluate functionalities: ***Matrix diagram***

The evaluate functionalities of A3AO is funkey and roadmap. The tool that is created in this category is the ***Matrix diagram***. The main action phases for Evaluate functionalities: ***Identify, Measurement, Repeat, Present***. The Identify main action phase can share the Listing tool to achieve its targeted goal of identifying functions and items. The ***Measurement*** main action phase gives us inspiration to use funkey standard organization forms and tables. The Matrix diagram is designed to handle the measurement of functions.

***Matrix diagram***: To easily handle and use funkey, and edit the elements inside, includes keydrivers and functions.

According to the Chapter A3AO functionality analysis, functionalities can be recognized as three main different types, each type has its related assistant tools. So, it should be noted that in create mode in the interaction, each time the user chooses functionality, the related tools will be lightened and the lighted tools are suggested tools to use and operate. But the tools that are not lighted can also be used as well. The lighted tools are more suggested and can help the users to easily select and create. The Table 1 shows the relationship between the functionalities and suggested create tools. And it will also be used when we design interactions of create tools. The symbol "x" means suggested tools that should be used.

**Table 5.1, Relationships between functionalities and suggested create tools.**

| Functionality | Create tools that suggest to use, and will be lightened when choosing (not lightened one also can be used) | | | | | | | | | | | | Note |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Text | Graphic | Shapes | Blocks | Colors | Listing | Grouping | Filter | Quantify | Fission | N2 | Matrix | |
| Stakeholders and System concerns | x | x | x | x | x | x | x | x | | | | | Category of summarize |
| Top view | x | x | x | x | x | x | x | x | | | | | |
| Parameters and system requirements | x | x | x | x | x | x | x | x | x | | | | |
| Physical view | x | x | x | x | x | x | x | x | | | | | |
| N2 diagram | x | x | x | x | x | x | x | x | | | x | | |
| Functional view | x | x | x | x | x | x | | | | x | | | Category of expand |
| Design strategies | x | x | x | x | x | x | | | | x | | | |
| Funkey | x | x | x | x | x | x | | | | | | x | Categroy of evaluate |
| Roadmap | x | x | x | x | x | x | | | | | | | |

## 5.5.3 Visualization of Create tools

**Figure 5.18, Icon of Text tool, and interface**

As is shown in the Figure 5.18, the interface of Text tool is a text box.

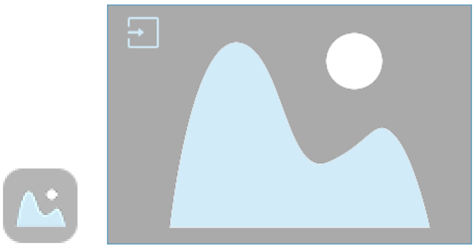


**Figure 5.19, Icon of Graphic tool, and interface**

As is shown in the Figure 5.19, the interface of Graphic tool has an import entrance.

**Figure 5.20, Icon of Shapes tool, and interface**

As is shown in the Figure 5.20, the Shapes tool interface includes circle, rectangle, triangle, line pen. These tools are most used to create regular and irregular shapes and lines.

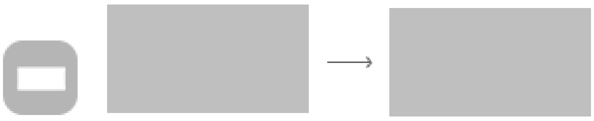


**Figure 5.21, Icon of Block tool, and interface**

As is shown in Figure 21, the Block tool are pointed out because it plays important role in graphical presentation of systems engineering. The user can easily use Block tool to organize their visualization purpose.

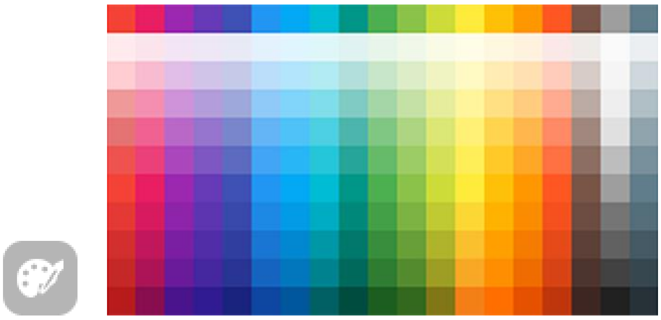


**Figure 5.22, Icon of Colors, and interface**

As is shown in Figure 5.22, the user can choose the color they want on the interface.

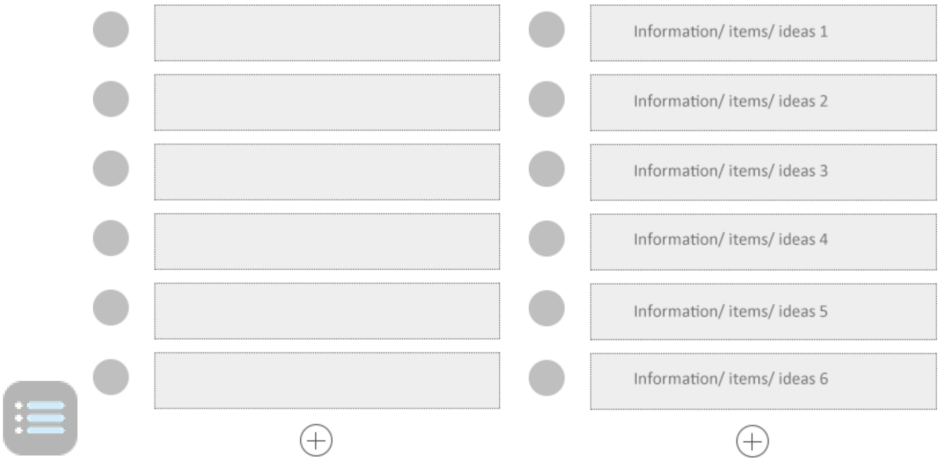



**Figure 5.23, Icon of Listing Tool, and interface of blank state and edited state**

As is shown in the Figure 5.23, user can input the information/item/ideas they want into blocks and click add button the table can be expanded.


**Figure 5.24, Icon of Grouping tool, and interface of blank state and edited state**

As is shown in Figure 5.24, users can drag the information/items/ideas they want into blocks to group them and click add button they can expand the blocks.

**Figure 5.25, Icon of Filter tool, and interface of the blank state and edit state**

As is shown in Figure 5.25, the user can input the information/items/ideas into the left blocks and write down their summaries into right block. Both sides' block can be expanded. This kind of using Filter tool can help users to summarize information.

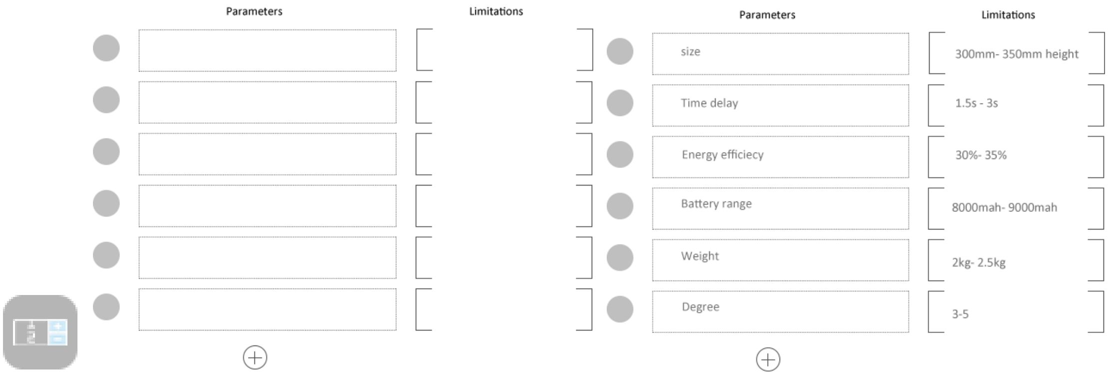



**Figure 5.26, Icon of Quantify tool, and interface of the blank state and edited state**

As is shown in Figure 5.26, the user can give quantifications by input parameters and their numerical limitations to quantify the systems requirements.

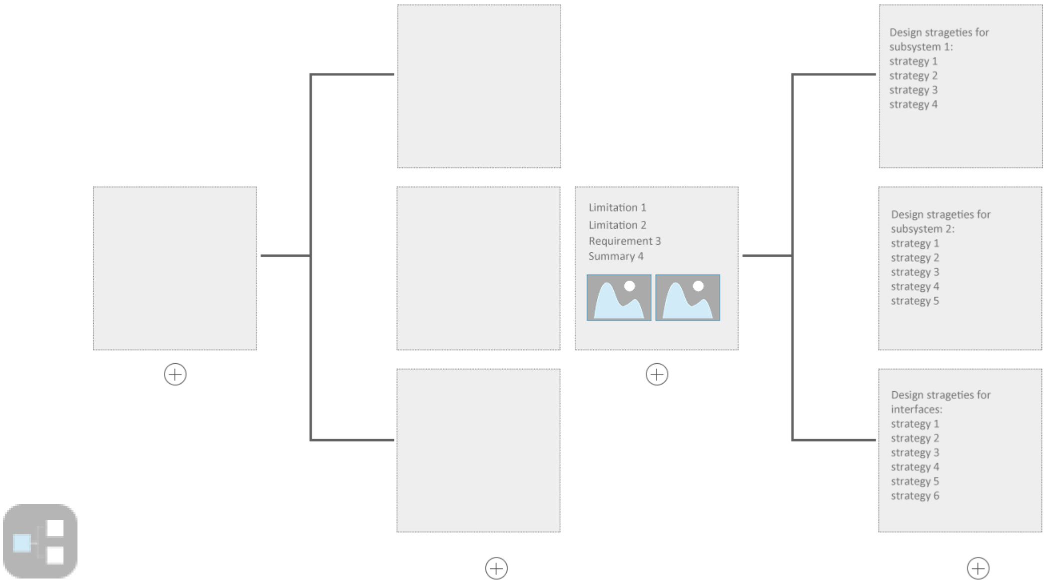



**Figure 5.27, Icon of Expand tool, and interface of blank state and edited state**

As is shown in Figure 5.27, the user input the limitation, requirements, summary on the left blocks and expand them into strategies on the right block to achieve the goal of expanding.

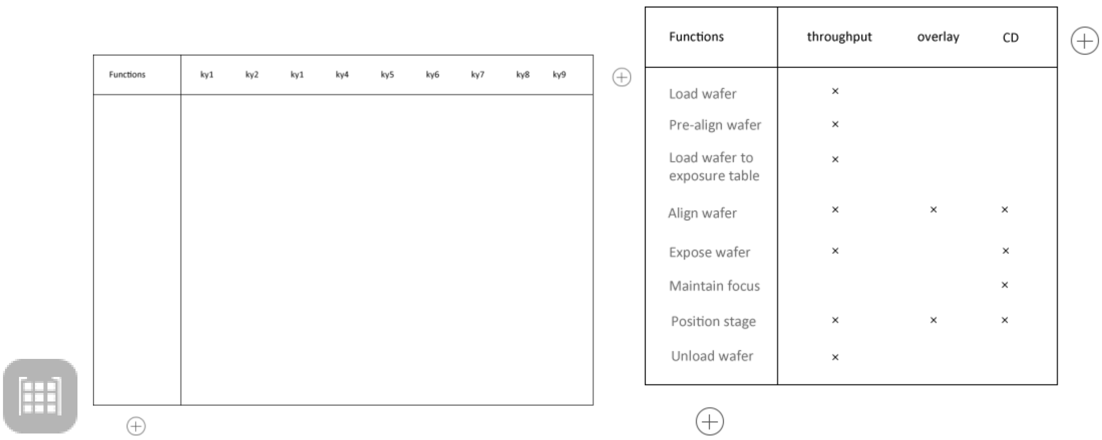



**Figure 5.28, Icon of Matrix diagram tool, and interface of blank state and edited state**

As is shown in Figure 5.28, the interface of Matrix diagram can input the functions and keydrivers, it is easy to click highlight inside the diagram. The add buttons can allowing adding more functions and keydrivers.

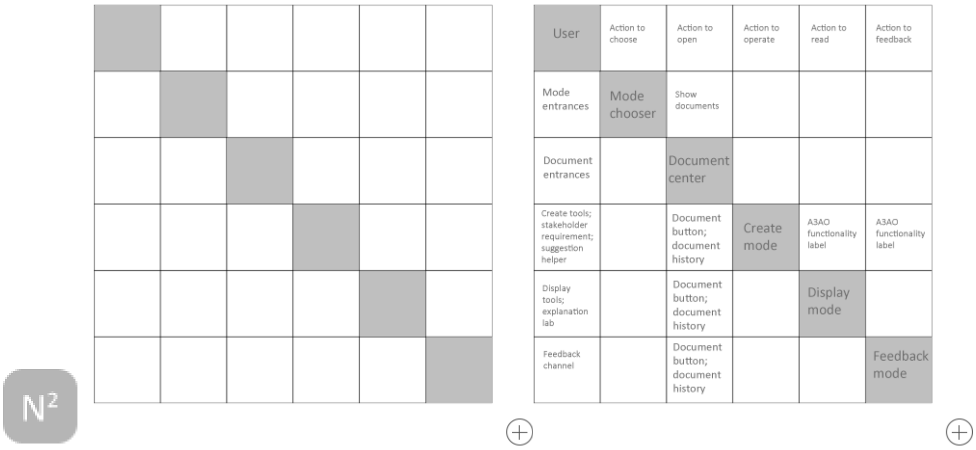



**Figure 5.29, Icon of N2 diagram tool, and interface of blank state and edited state**

As is shown in the Figure 5.29, the user can input the functions/activity into dark grey blocks , and write interfaces of systems in white blocks to complete the N2 diagram.

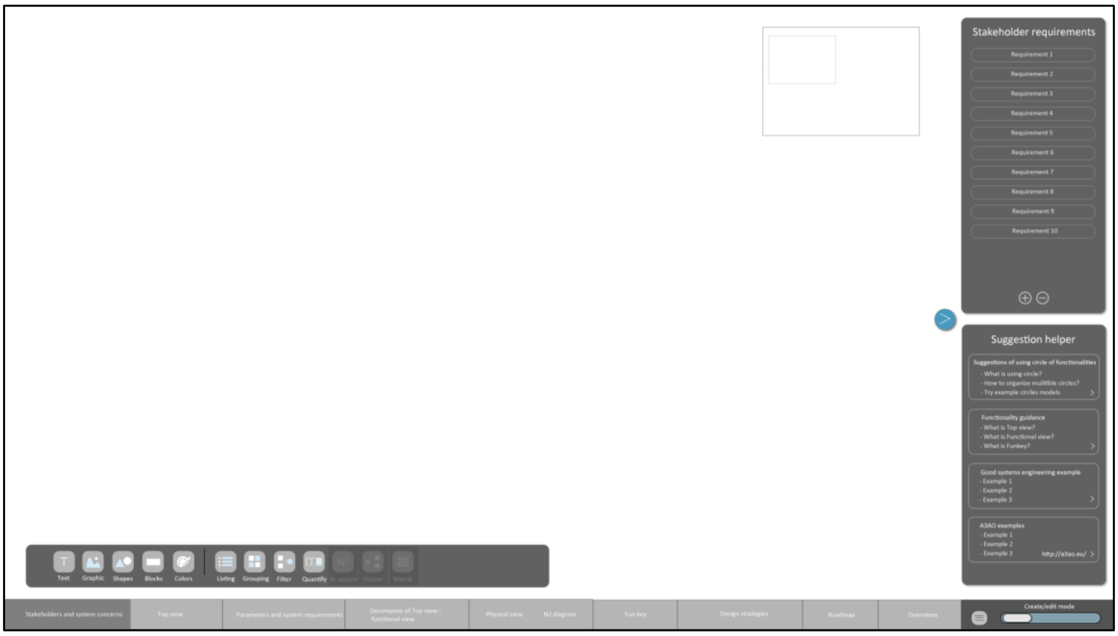



**Figure 5.30, Screenshot of interaction demo choose functionality**

As is shown in Figure 5.30, the user can choose what kind of functionality they want to create and related tools will be lighted, it should be noted that nonlighted tools can also be used. The relationships inside can be seen in Table 5.1, which clearly shows the suggested tools.

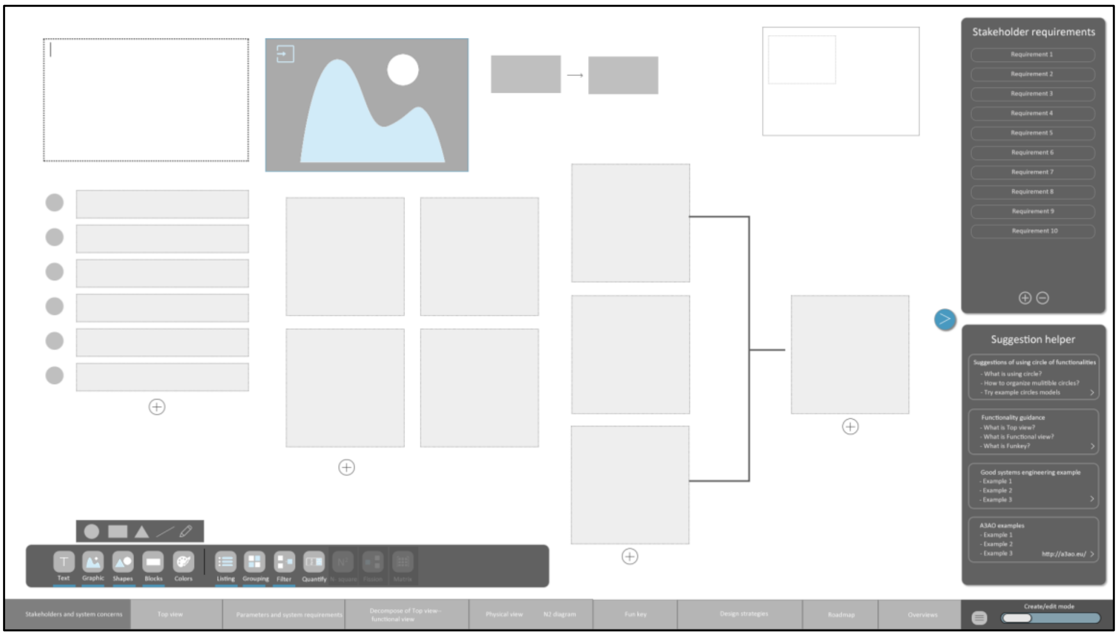



Figure 5.31, Screenshot of interaction demo using create tools

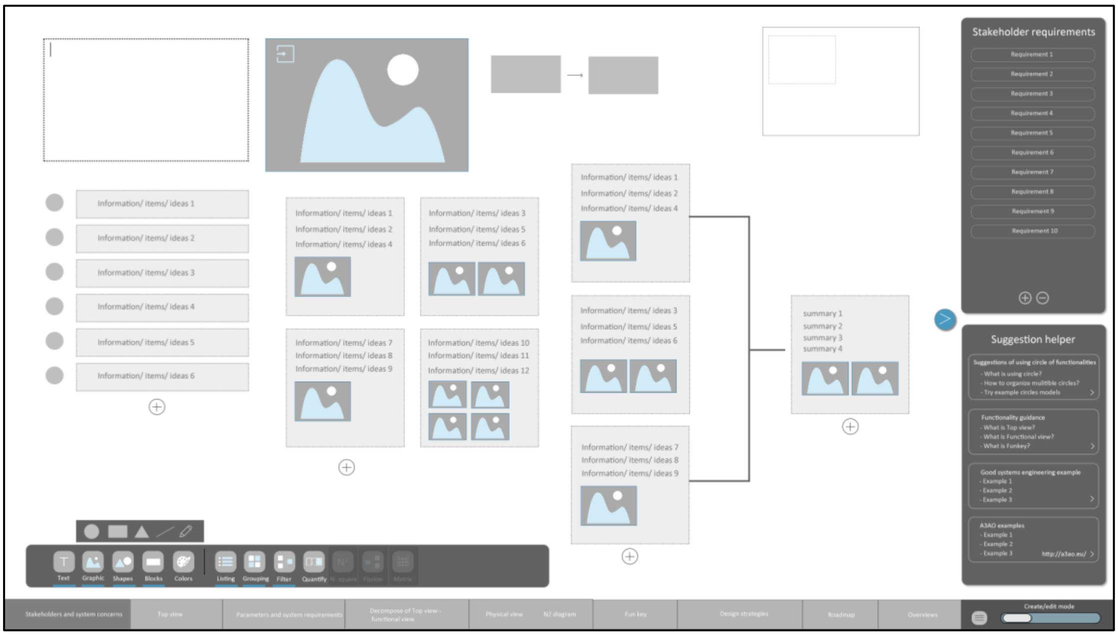



Figure 5.32, Screenshot of interaction demo using create tools to edit

More screenshots can be seen on Appendix 1

# 5.6 Demo

## 5.6.1 Demo running on devices

The A3AO manipulate center' demo is developed as an html demonstration. And it is proved to be able to run well in Laptop devices and touch screen devices. The default resolution is 1920*1080. Both the mouse with keyboard and fingers can handle the interaction. The A3 sized screen device- XPS 18 can also run this demo well. These are the screenshots of the interaction and photos about demo on devices. As is shown in the Figure 5.33, and Figure 5.34, the demo can be operated by the touch interactions fluently.

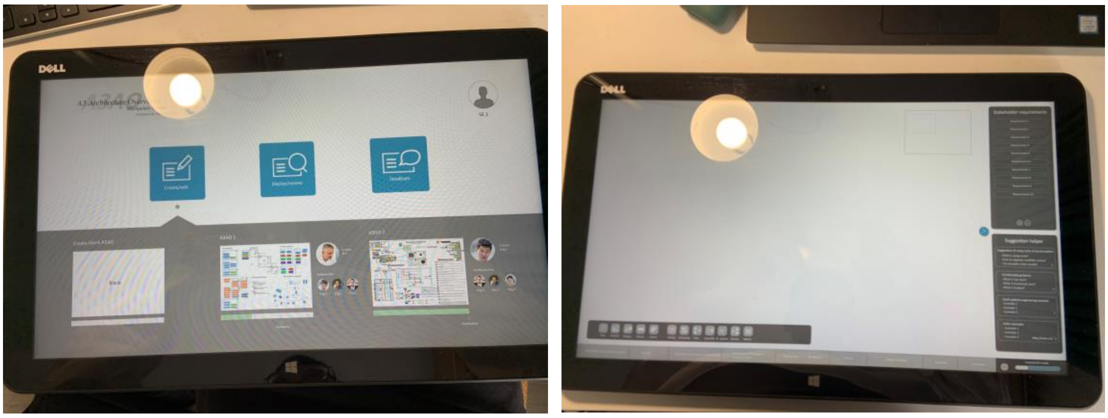


**Figure 5.33, Demo running on Touchscreen devices**

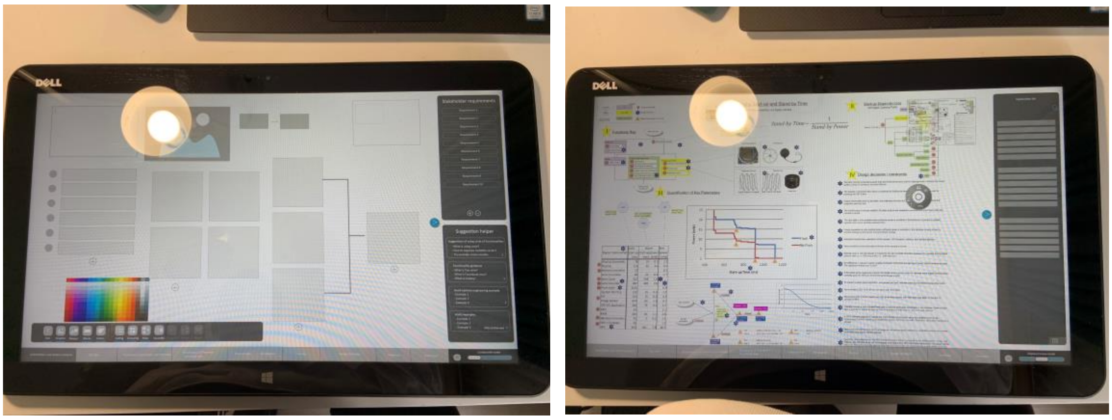


**Figure 5.34, Demo running on Touchscreen devices**

## 5.6.2 Demo making description

The interaction demo making software Axure RP is used in making demo, and the output is a pack of html documents. It is usable in UX design and has strong ability to simulate a good performing demo.

Software used： Axure RP
Software version:   9.0
Development background: Windows

## 5.6.3 Movie of operation

The movie of description of the design and operations on demo is also made, the movie includes all useful information in this chapter. It is about the three modes interface review and

description, and the actual demo running on touch screen devices.
The link of the video: https://youtu.be/Szn_zEN9qkw
It is strongly suggested to watch the video to deeply understand the design.

# 6. Discussion

## 6.1 Further development of A3AO interactions

**First part will discuss the design result A3AO manipulate center extension and its future development.**

### 6.1.1 Relationship with current systems engineering tools

The A3AO manipulate center is develop as a systems engineering related tool, it is needed to discuss its relationship with current systems engineering tools. We try to compare it with current systems engineering tool Capella. And the tips below are what want to emphasize.

1) The current systems engineering tools follow different systems engineering development structures, the building procedure and logic have some differences. Comparatively, the A3AO is more flexible on using functionalities.
2) The usability and using logic of Capella are not good, and it is not friendly to new users. The engineering results are also quite hard to review.
3) The basic components inside the development can be shared, such as FBD (Function block diagram), physical structures. It requires the A3AO manipulate center can identify and abstract useful components from Capella tool files.
4) There are differences between Text based systems engineering, or Model based systems engineering (MBSE), according to Knizhnik, J. R. L., Pawlikowski, G., & Holladay, J. B. In default settings, the A3AO documents is a Text based approach, but the A3AO manipulate center should be open for Model based SE interfaces and ports. The SE models can be inserted or linked to the A3AO specific functionalities. The MBSE components can also be plugins for the A3AO functionalities. The MBSE components might be closer to advanced specifications. So, the plugin ports and interfaces should be remained for A3AO manipulate center future development.

### 6.1.2 The problems in future development phases:

1. Crossing devices compatibility

The A3AO manipulate center is designed to be compatible for PC, tablet(pads). And should be able to output in large size monitors/televisions.

The interactions are designed in a medium way, and they can both be read and edited by PC income devices (keyboard and mouse) and touchscreens (only screens). But generally, the PC with keyboard is easier to do creating editing operation. If we want to use touch screens to do more convenient editing operations, some editing interactions should be adjusted to be more direct for touchscreens users.

The demo shows that the reading and feedback modes can run well both in PC and touch screen devices. And the capability problems will not happen in these two modes.

2. Document format compatibility

Currently nearly all A3AO documents are displayed in PDF. The default saving format or output format can be PDF, and it will be a kind of Interactive PDF document.

However, there is still problems that whether interactive PDF can record the functionality type information. Because the A3AO manipulate center all modes rely on the labels of A3AO functionalities, how to insert them will be a problem.

The interactive PDF will also not record the history of the editing, and discussions, some functions inside the manipulate center will be limited if only using interactive PDF as only format to save.

A defined document format can be created for A3AO manipulate center, it should meet the needs below:

***1. It can record the functionalities labels in the document***

***2. It can record editing history in the document***

***3. It can record discussion history and status in the document***

***4. It can record editors, reviewers information in the format.***

***5. It be able to have access management for reviewers.***

***6. It can record the documents status (created, reviewed, and feedbacked)***

***7. It can be open for future MBSE components as plugins.***

***8. It can be forced to be open by PDF reader software, and most content can be displayed.***

### 6.1.3 Current systems engineering tools compatibility

As is discussed before, to be some extent compatible for current systems engineering tools are also important in the future. And there will be two dimensions compatibilities.

The first is to be able to import systems engineering basic components from other SE development tools, such as FBD, physical structure, parameters and so on. To be more specific, the A3AO manipulate center can read and abstract these useful components from current SE tools document formats.

The second is to be able to import MBSE components as links or plugins. The MBSE components can be linked or plug to the A3AO functionalities. It requires the interfaces remaining for these MBSE components when develop software.

## 6.2 Observations on systems engineering and design discipline

**Second part will focus on observations on systems engineering and design discipline and combining them.**

### 6.2.1 Using A3AO/systems engineering in interaction design

As is introduced in Chapter interaction frame, section 4.1, there are three main approaches in Interaction design discipline- User centered design, Scenario based design and Cognition based design. However, when facing interactions in complex situations and have requirement on achieving large number of functions, current design approaches sometimes would encounter problems. To consider interaction design as a system and apply systems thinking/ systems engineering method into interaction design could be worthy to have more development.

In Chapter interaction frame, the definition of interaction system is *The developed interaction system can be defined as a set of interactive functions and operations that can guide creating visualizations of the system under design that meets the requirements of stakeholders.* Based on this definition, there are three key components inside the interaction system: Stakeholder requirements, functions and operations, visualizations. To develop a qualified interaction system in fact is to develop well-performed system that cope well with Stakeholder requirements. Functions and operations, and Visualization. The systems approach can be introduced into the interaction system development especially the Functions and operation phase.

In interaction system development, we can regard the Stakeholder research as input. Then we use system approach to generate and organize functions and operations. After that, we can get an interaction frame which could be used to guide the visualization. The procedure is shown in Figure 6.1.

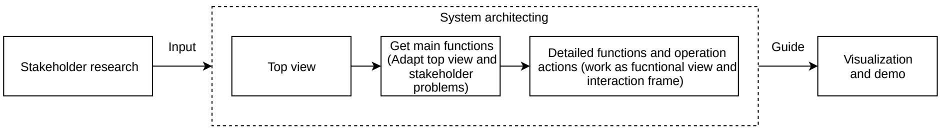



**Figure 6.1, Using system architecting in interaction system**

Apply A3AO and SE into interaction design

This assignment itself is an application of using A3AO/system engineering to do interaction design, and the tips below is the concluded steps:

***1. User or stakeholder research***

***2. Top view of interaction***

***3. Adapting Top view and user problems- get user requirements/possible solutions- get subsystems (main functions)***

***4. Functional view- expand top views and main functions- get details of the interactions. It will work as interaction frame.***

***5. Building visual interaction components based on functional view***

***6. Visualization and prototype***

The procedure shown is an attempt to use systems approach, other systems tools can also be used such as funkey, which can be used to measure the importance and priority of interaction functions, and N2 diagram, which can be used to find internal logic and information currency inside between functions. The use of systems tools depends on practical situation and actual development requirement.

### 6.2.2 Integrate current design methods into A3AO and Systems engineering

In fact, if we want to use A3AO and systems approaches into interaction design, it is possible to take existing design domain methods and combine them together with A3AO functionalities embedded.

1. We can try to use *Design methods and tools* (Scenario design, Service design, Multisensory design, Platform design, TRIZ, SWOT …… and so on) as input into A3AO functionalities.

For example, insert Scenarios into Stakeholder requirements functionality part.

2. Typical design method and tools can serve as new functionalities (platform design, TRIZ, SWOT)

## 6.3 Reflection and statement about systems engineering

**Third part will concentrate on reflection of systems engineering evolving and statement about systems engineering.**

According to the deep interview of current industry engineers, it can be found that the systems engineering is still in developing; one of the main challenges might be the adaptation between endless changing environment (especially for the environment which the systems are designed to give solutions) and fixed once-time systems design. To extend the systems adaptation and usage time, approving more flexibility and interfaces in system design for latter environment might be a good choice. Based on the total research's understanding that the systems engineering is constantly evolving, and the environment which the systems are designed for is also constantly evolving, we can try to give statements of systems understanding.

The three statements about systems engineering are proposed after all the research, and they can provide inspirations and could work as principles to measure systems architecture and systems engineering development.

***1. The essence core of system relationships is the relationship between the whole and components. The relationship between components and components also has important influence.***

***2. The components of the system and the system itself are always evolving, and the evolution advances with the time and is influenced by the environment.***

***3. The architecture of the system can be considered as relative stable after the components are organized.***

# 7. Conclusion

1. The research begins with stakeholders' research which focuses on Asian high tech companies and students, exploring the working process of system and product development. Two kinds of working process are concluded, document driven process and meeting driven process. It also results with stakeholders' traits and problems they face in system development.
2. By observing and analyzing A3AO functionalities, the functionalities are concluded as three types: to summarize, to expand and to evaluate. A using loop for three types is purposed. It is concluded that there exists a using loop in A3AO functionalities: summarize, expand, evaluate. The derived tips to organize A3AO functionalities using are also resulted. Three main kinds of loops of using A3AO functionalities are also proposed: single loop, one loop with multiple functionalities, several loops integrate with each other.
3. According to the three type definitions, A3AO functionalities are decomposed. The main action phases of same category functionalities are concluded, which give inspirations and support for designing the create tools to create A3AO. Based on inspiration of A3AO functionality decomposition, a series of create tools are developed to realize the usage stage of creating A3AO documents.

Based on the interaction frame, a series of design are created. The design includes 3 modes based interaction which covers the main usage of A3AO. The demo is developed as HTML interfaces and the demo runs well on A3 sized touch screen tablet and PC. A lot of suggestions are also given to further develop this interaction.
4. This assignment also proposes an attempt of using A3AO and systems engineering in interaction design. The process can be

1. *User or stakeholder research*
2. *Top view of interaction*
3. *Adapting Top view and user problems- get user requirements/possible solutions- get main functions*
4. *Functional view- expand top views and main functions- get details of the interactions*
5. *Building visual interaction components based on functional view*
6. *Visualization and prototype*

5. The research also proposes statements on systems engineering understanding based on the total research content. These are the statements:

1. *The essence core of system relationships is the relationship between the whole and components. The relationship between components and components also has important influence.*
2. *The components of the system and the system itself are always evolving, and the evolution advances with the time and is influenced by the environment.*
3. *The architecture of the system can be considered as relative stable after the components are organized*

# References

Abras, C., Maloney-Krichmar, D., & Preece, J. (2004). User-centered design. Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications, 37(4), 445-4

Anggreeni, I., & van der Voort, M. (2007). Tracing the Scenarios in Scenario-Based Product Design A study to support scenario generation. Design Principles and Practices: An International Journal, 2(4), 123-136.

Baldwin, C. Y., Clark, K. B., & Clark, K. B. (1999). Design rules: The power of modularity (Vol. 1). MIT press.

Blanchard, B. S. andW. J. Fabrycky: 1998; Systems Engineering and Analysis; Prentice Hall, Upper Saddle River, New Jersey; 3rd edn.

Blikstein, P., Sipitakiat, A., Goldstein, J., Wilbert, J.,Johnson, M., Vranakis, S., Pedersen, Z., & Carey, W.(2016). Project Bloks: designing a development platform for tangible programming for children. Position paper, retrieved online on 2016-06-30.

Bonnema, G. M. (2008). Funkey architecting: an integrated approach to system architecting using functions, key drivers and system budgets.

Bonnema, G. M., Veenvliet, K. T., & Broenink, J. F. (2016). Systems design and engineering: facilitating multidisciplinary development projects. CRC Press.

Brussel, F. F., & Bonnema, G. M. (2015). Interactive A3 architecture overviews: intuitive functionalities for effective communication. Procedia computer science, 44, 204-213.

Carter, J. C., Aimé, A. A., & Mills, J. S. (2001). Assessment of bulimia nervosa: A comparison of interview and self-report questionnaire methods. International Journal of Eating Disorders, 30(2), 187-192.

Daniel Borches (2010). A3 Architecture overviews. A tool for effective communication in product evolution.

Davidz, H. L., D. J. Nightingale and D. H. Rhodes (2004). Enablers, barriers, and precursors to systems thinking development: The urgent need for more information. INCOSE International Symposium 2004. Las Vegas, INCOSE. System thinking

Dourish, P. (2001). Where the Action is. Cambridge, MA: MIT Press.

Dumas, J. S., & Redish, J. C. (1993). A Practical guide to usability testing. Norwood, NJ: Ablex.56.

Frank, M. (2006). "Knowledge, abilities, cognitive characteristics and behavioral competences of engineers with high capacity for engineering systems thinking (CEST)." Systems Engineering, The Journal of the International Council on Systems Engineering 9(2): 91-103.

Gray, P. (2010). Business anthropology and the culture of product managers. Association of Product Management and Product Marketing (AIPMM).[pdf file, retrieved September 21, 2011, from http://www. aipmm. com/html/newsletter/archives/BusinessAnthroAndProductManagers. pdf].

Halman, J. I., Hofer, A. P., & Van Vuuren, W. (2003). Platform-driven development of product families: linking theory with practice. Journal of product innovation management, 20(2), 149-162.

Hooft, D. T., de Kroon, J., van Omme, D., & Bonnema, G. M. (2020, July). Enabling systems engineering in a new product development process via a tailored A3 architecture overview

approach. In INCOSE International Symposium (Vol. 30, No. 1, pp. 168-182).
Horowitz, B., & Weiden, D. (2010). Good Product Manager Bad Product Manager. Andreessen Horowitz website (no exact date given), a16z. com/2012/06/15/good-product-manager bad product-manager.
Isight & SIMULIA Execution engine: Dassault Systèmes®. (n.d.). Retrieved August 17, 2021, from https://www.3ds.com/products-services/simulia/products/isight-simulia-execution-engine/
Kirsh, D. (2013). Embodied cognition and the magical future of interaction design. ACM Transactions on Computer-Human Interaction (TOCHI), 20(1), 1-30.
Knizhnik, J. R. L., Pawlikowski, G., & Holladay, J. B. Systems Engineering & Model Based Systems Engineering State of the Discipline. In Systems Engineering & Model Based Systems Engineering State of the Discipline Webcast.
Kordova, S., Katz, E., & Frank, M. (2019). Managing development projects—The partnership between project managers and systems engineers. Systems Engineering, 22(3), 227-242.
Lano, R. (1977). The N2 chart. TRW Software Series.
Maher, M. L., Gero, J., Lee, L., Yu, R., & Clausner, T. (2016, July). Measuring the effect of tangible interaction on design cognition. In International Conference on Augmented Cognition (pp. 348-360). Springer, Cham.
McGrath, M. E. (1995) Product Strategy for High Technology Companies, Irwin Professional Publishing, New York.
Sheard, S. A. (1996, July). Twelve systems engineering roles. In INCOSE International Symposium (Vol. 6, No. 1, pp. 478-485).
Simpson, J. J., & Simpson, M. J. (2009). System of Systems Complexity Identification and Control.
Sutton, J. (2006). Introduction: Memory, Embodied Cognition, and the Extended Mind. Philosophical Psychology, 19(3), 281–289.
Van Gennip, D., Orth, D., Imtiaz, M. A., van den Hoven, E., & Plimmer, B. (2016, November). Tangible cognition: bringing together tangible interaction and cognition in HCI. In Proceedings of the 28th Australian Conference on Computer-Human Interaction (pp. 662-665).
Walden, D. D. (2007, April). The changing role of the systems engineer in a System of Systems (SOS) environment. In 2007 1st Annual IEEE Systems Conference (pp. 1-6). IEEE.

# Appendix 1

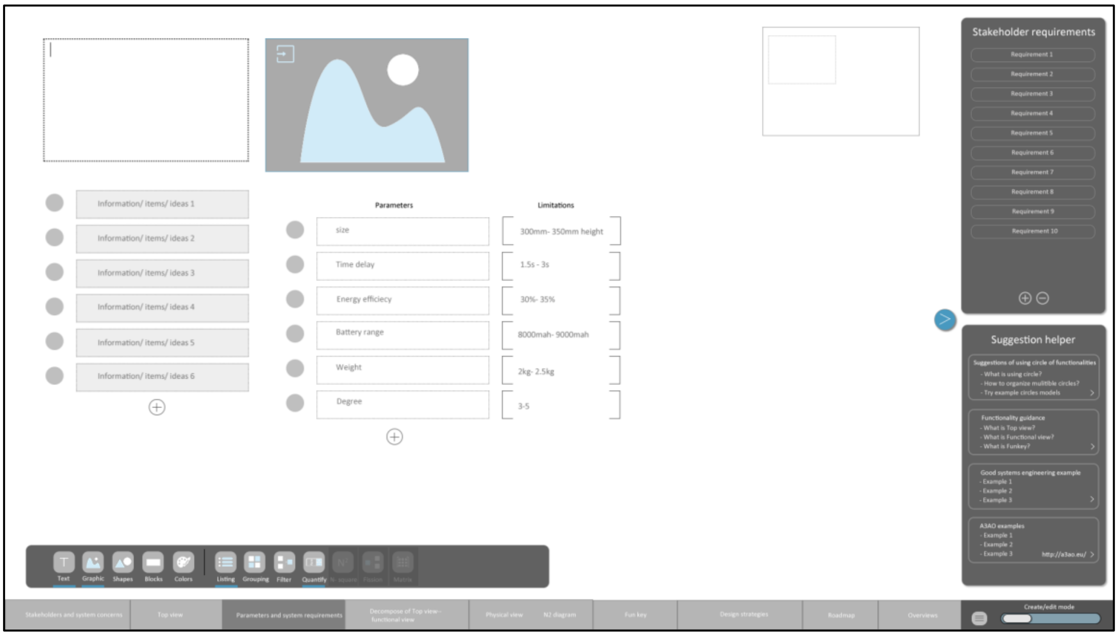



Figure a.1, Screenshot of interaction demo using create tools to edit

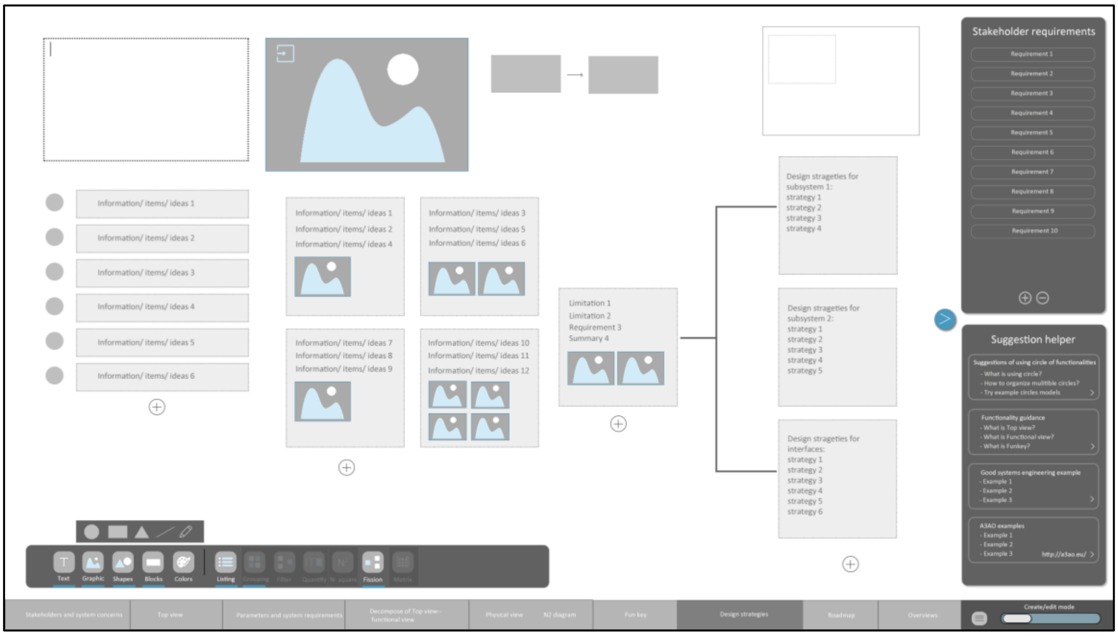
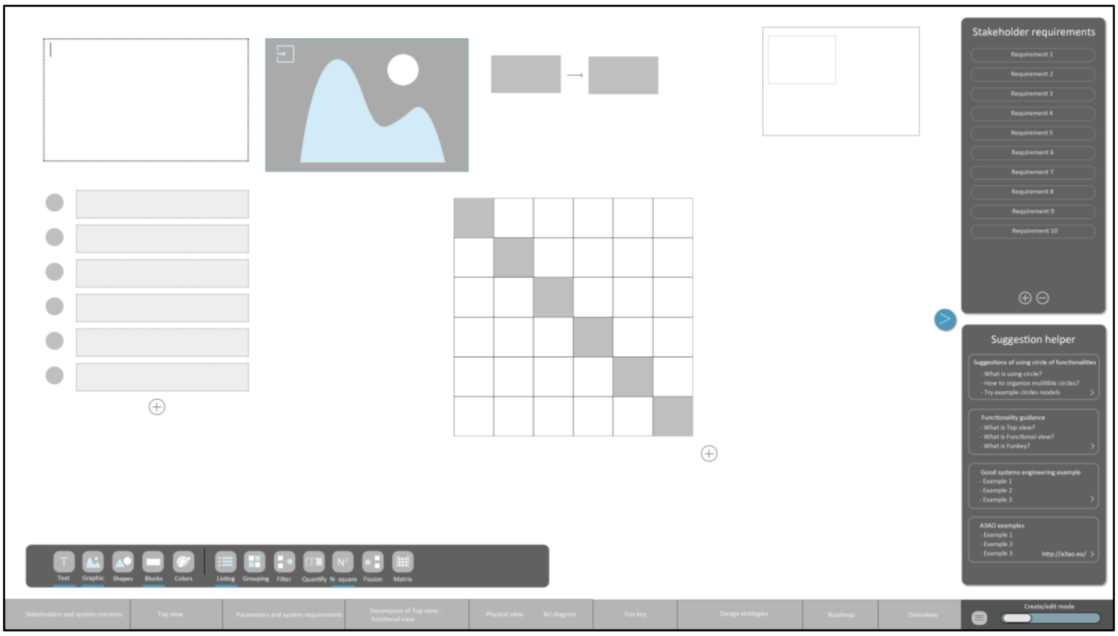



Figure a.2, Screenshot of interaction demo using create tools to edit




Picture a.3, Screenshot of interaction demo flexible use of create tools

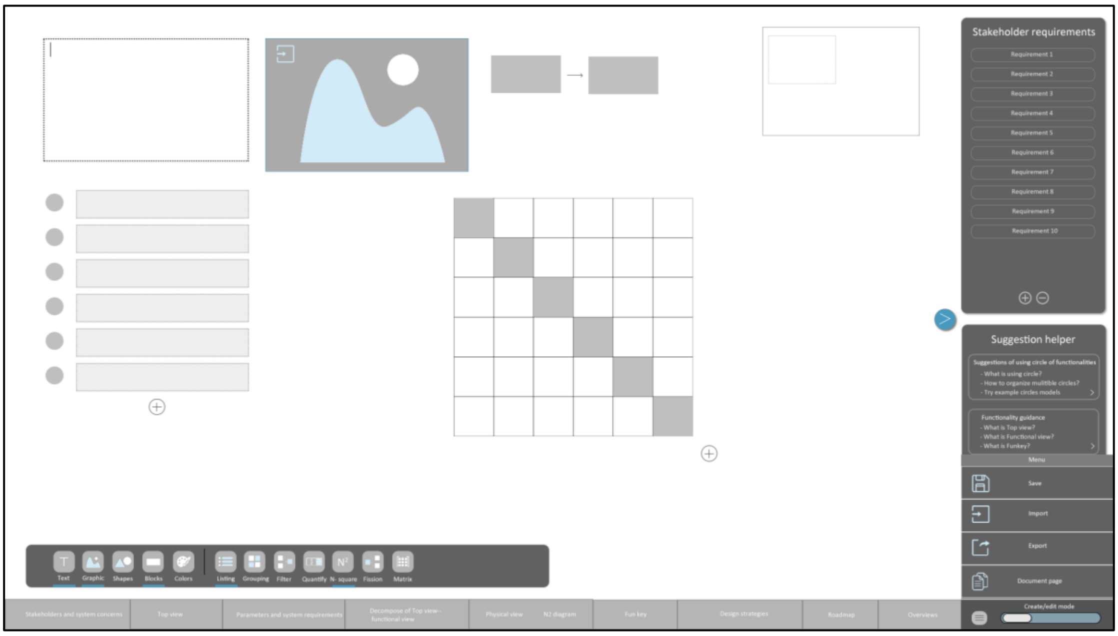



Figure a.4, The menu of create page

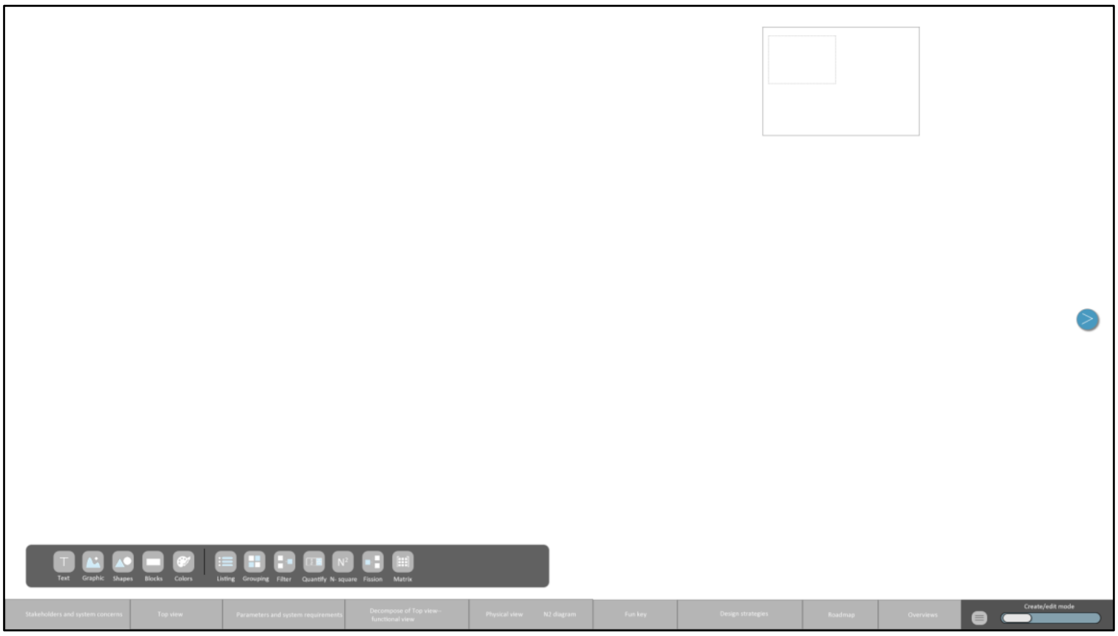



Figure a.5, Screenshot of hiding side bars

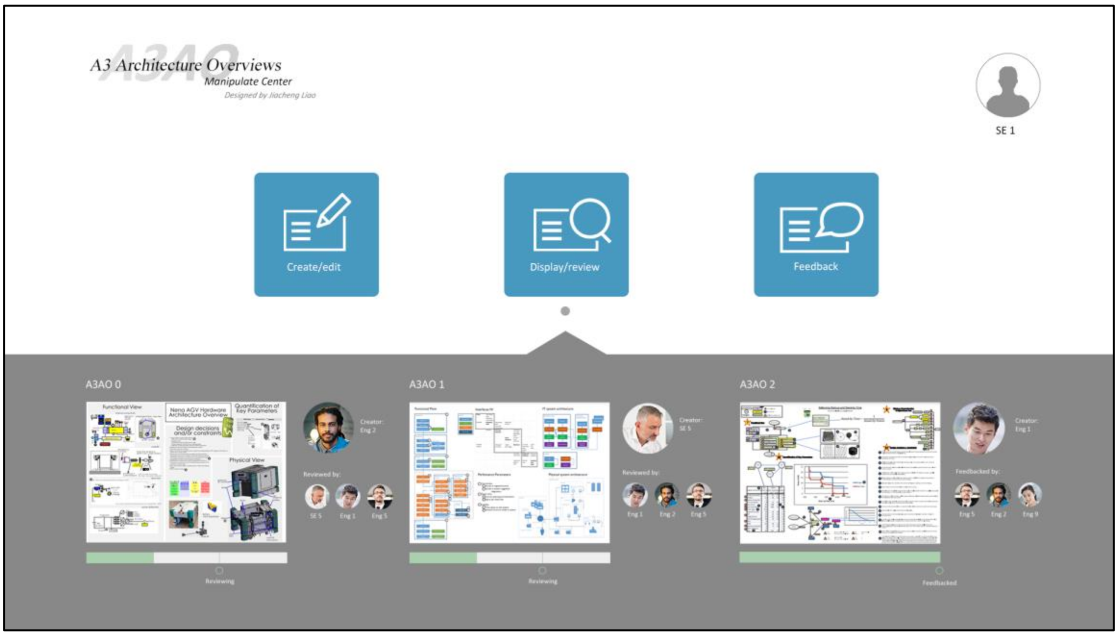



Figure a.6, Screenshot of menu page

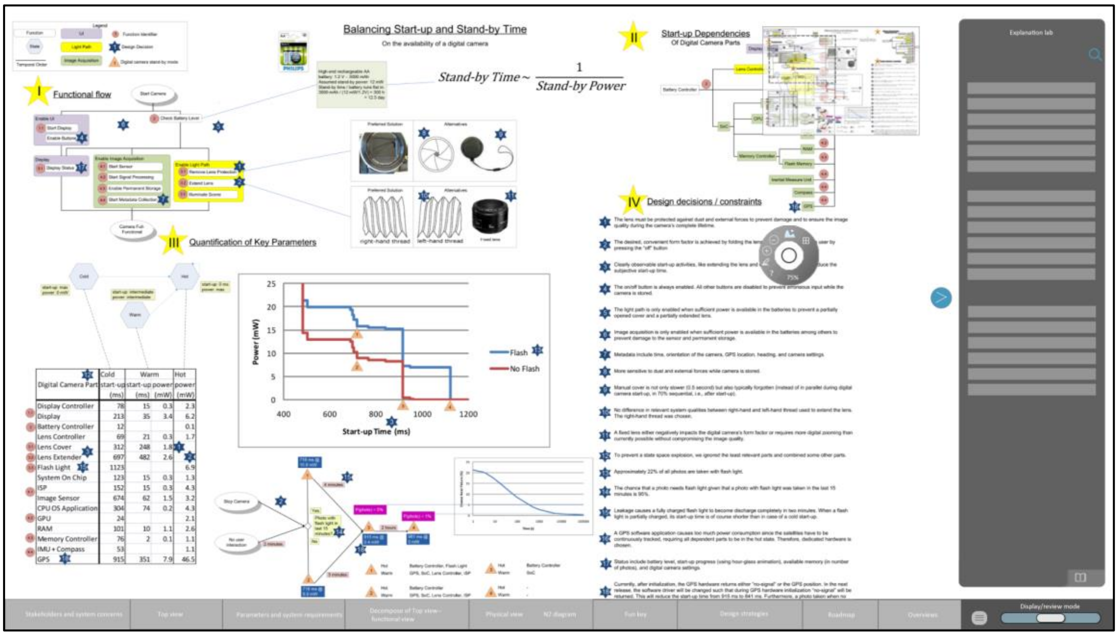



Figure a.7, Screenshot of design demo display mode page

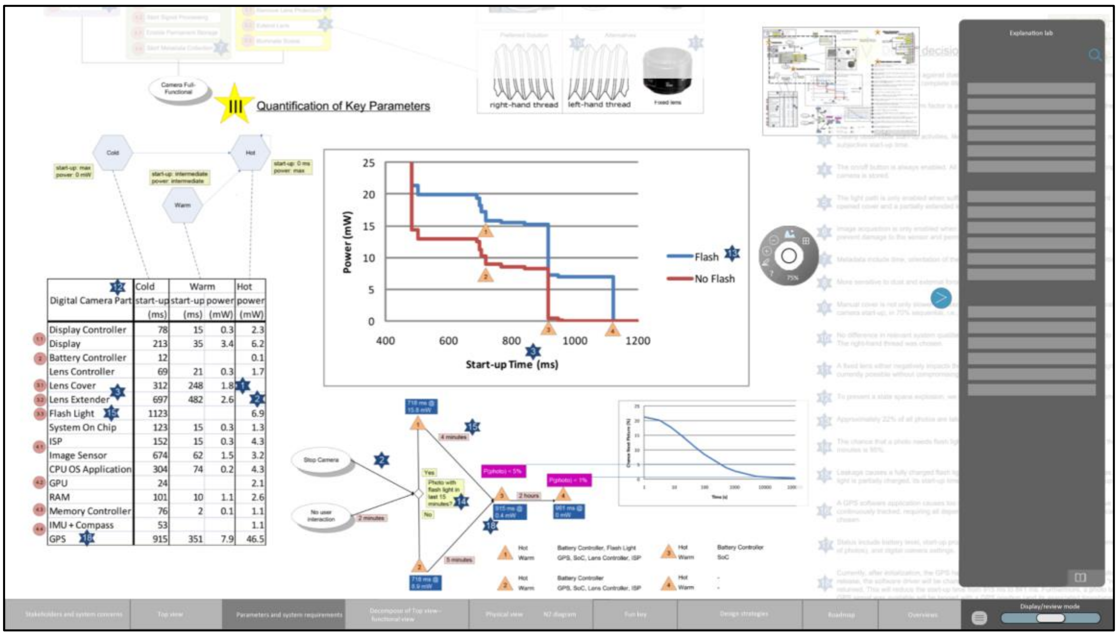



Figure a.8, Screenshot of design demo display mode page zoom in

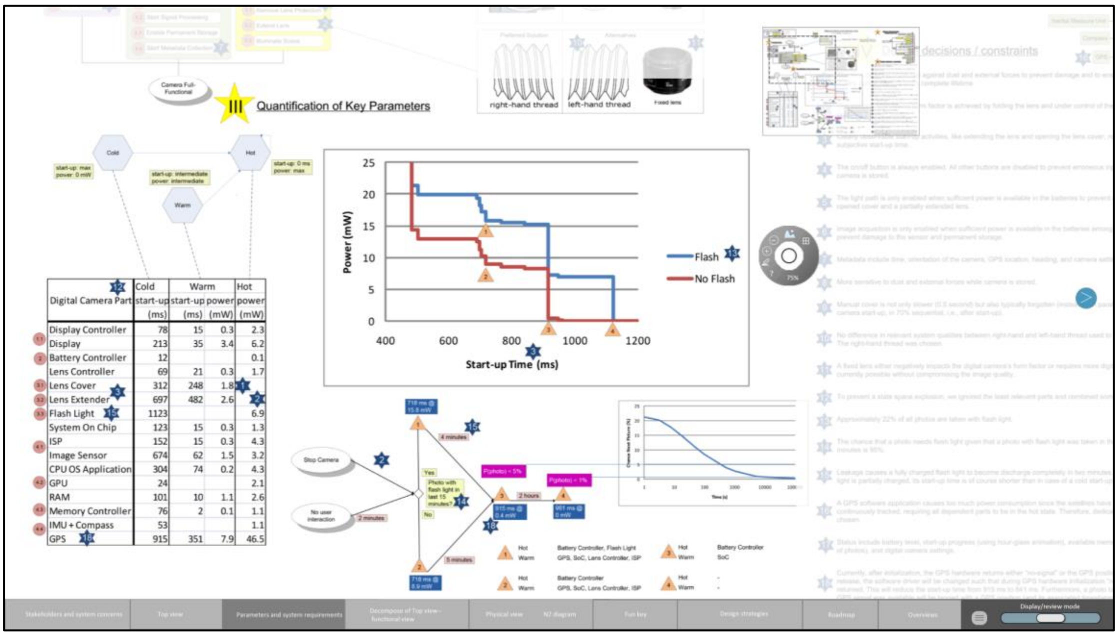


Figure a.9, Screenshot of hiding side bars

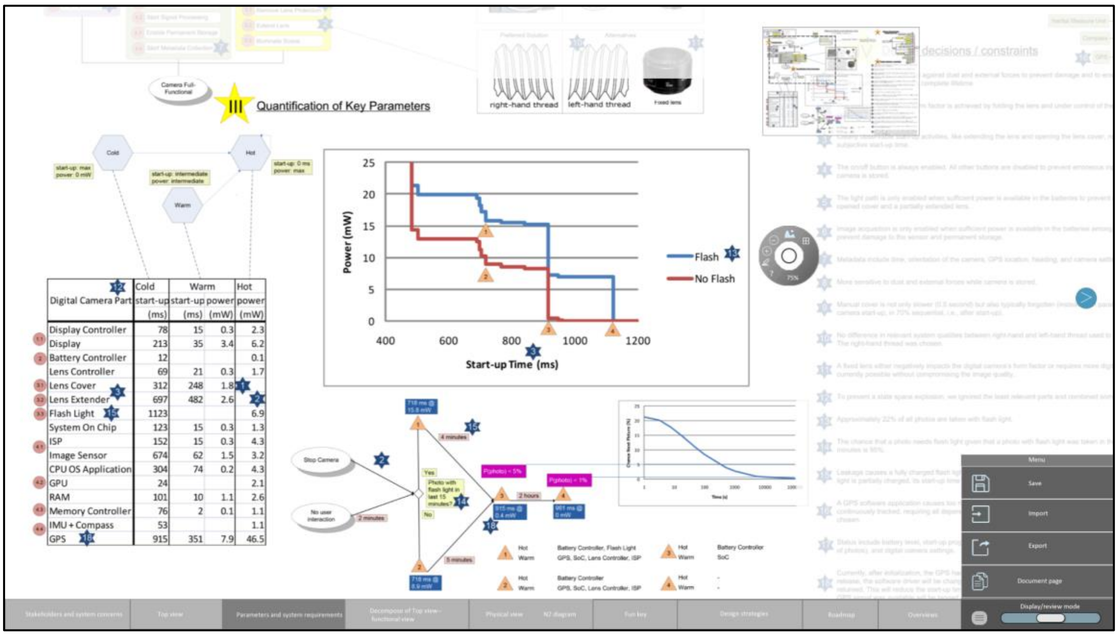


Figure a.10, Screenshot of Menu in display mode

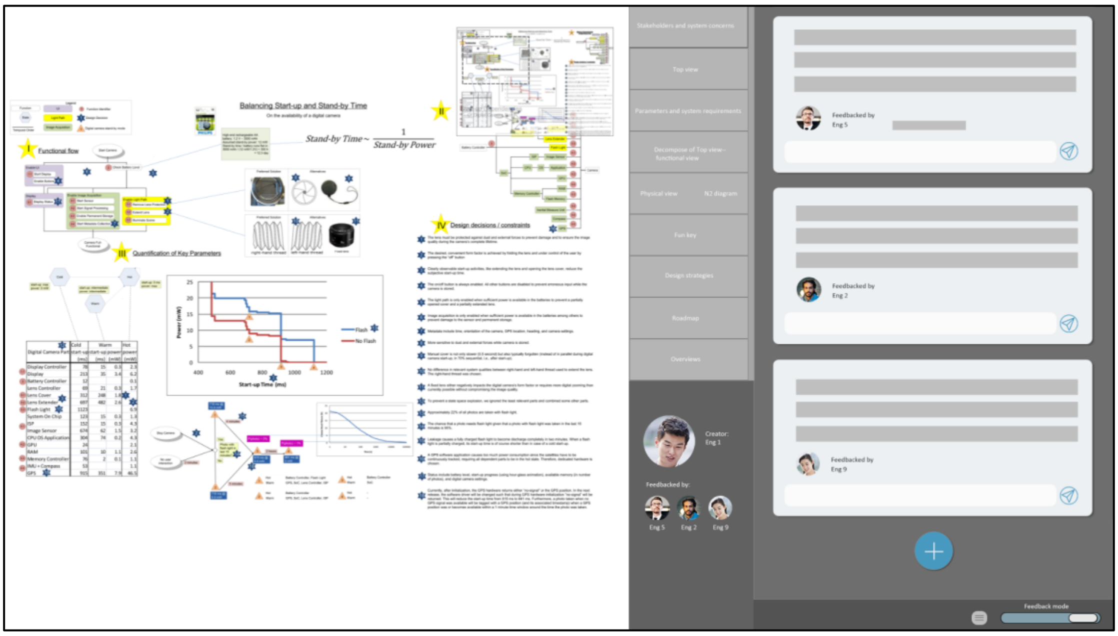


Figure a.11, Screenshot of design demo feedback mode page

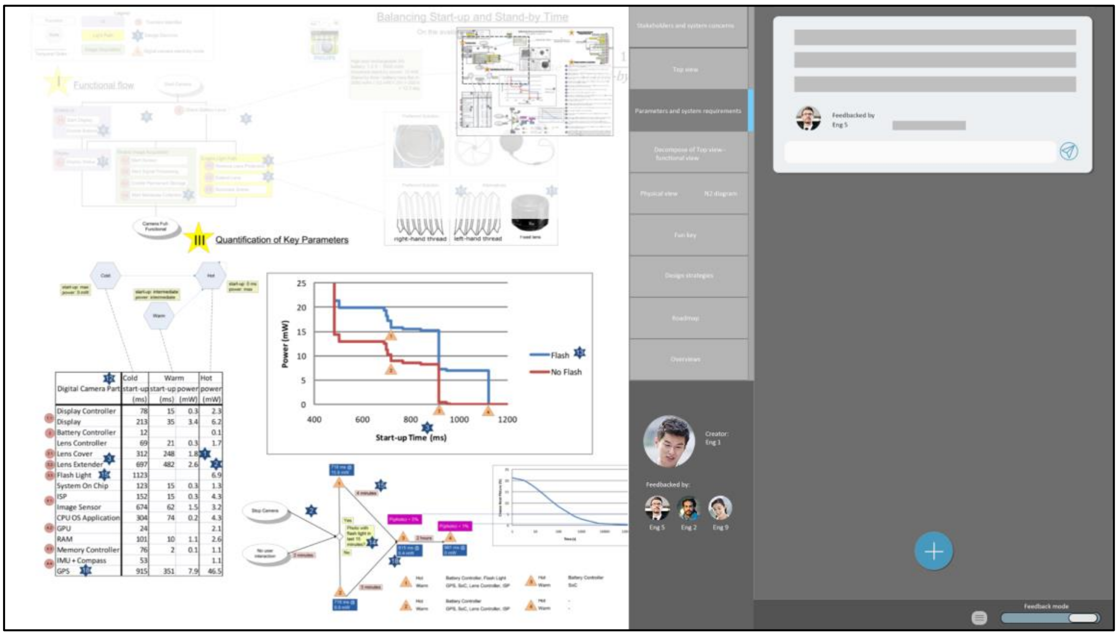


Figure a.12, Screenshot of design demo feedback mode page 2