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Layout and Design of Information for Air Traffic Control

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Submission date: June 2016
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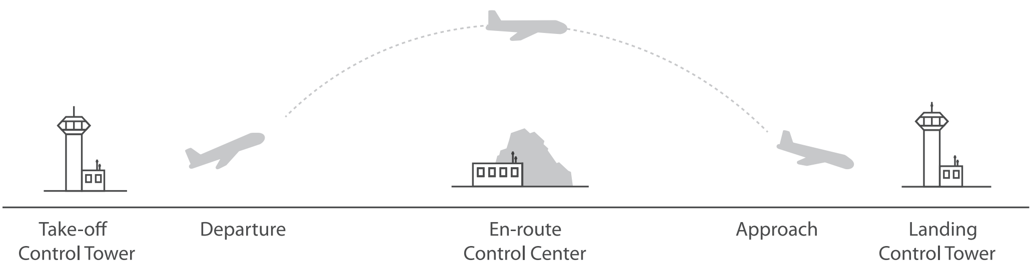


A user-centered approach, combined with research and theory, to develop informational weather graphic for air traffic controllers.

Preface

This master's thesis has been written at the Department of Product Design at the Norwegian University of Science and Technology, during the spring 2016.

The thesis describes and documents an exploration of the subject of air traffic control. It describes insights gained when getting to know air traffic controllers and other relevant stakeholders, as well as needs and theory found relevant in the work of the air traffic controllers. Further, it describes a proposed solution developed during the project.

I would like to thank my supervisors Trond Are Øritsland and Thomas Porathe for guidance and support throughout the semester. Additionally, I would like to thank my fellow students at the Department of Product Design; Marianne, Kjersti, Alexander and Jan-Magnus for the team-up in fieldwork and workshops.

Thank you to Alf Ove Braseth, and the rest of the team at IFE for the thesis idea, guidance and collaborations along the way.

Thanks to the class of 2016 for five years of great discussions and laughs.

Thank you to my family, boyfriend, and friends for support, inspiration and encouragement throughout the project. It has been greatly appreciated.

Finally, I would like to thank all those who have contributed with insight, feedback and reflection throughout the fieldwork, concept development and testing.

Thank you.

Abstract

Air traffic control is important for safe and efficient navigation in controlled airspace. A crucial factor is the weather information provided to the Air Traffic Controllers (ATCOs). A particular challenge is the weather phenomena Cumulonimbus (Cb), a type of cloud causing e.g. thunderstorms and icing. However, the technology of predicting such weather is still in development and there is no common practice of how to visualize this information on the ATCO's radar screen. This master's thesis proposes a solution for visualizing Cb graphic on the radar screen, communicating necessary information and its uncertainty. The information graphic is developed through a user-centered design (UCD) approach. Interaction design methodology is combined with previous research and theory on e.g. information visualization and situation awareness to accommodate the ATCO's needs and ensure safety measures. The resulting information graphic is implemented in a full-scale training simulator. Small-scale usability testing proved how the new graphic is intuitive and contains the necessary information. As technology develops, more research should be done on this subject, especially on how more precise information can be included.

Sammendrag

Flykontroll er viktig for trygg og effektiv navigering i kontrollerte luftrom. En avgjørende faktor er værinformasjonen flygelederne mottar. En særlig utfordring er værfenomenet Cumulonimbus (Cb), en type sky som fører til e.g. tordenvær og ising. Teknologien for å forutse dette været er under stadig utvikling, og det finnes ingen felles praksis for hvordan slik informasjon skal visualiseres på radarskjermen til flygelederne. Denne masteroppgaven foreslår en løsning for visualisering av Cb-grafikk på radarskjermen som kommuniserer nødvendig informasjon og tilhørende usikkerhet. Informasjonsgrafikken er utviklet ved hjelp av en brukersentrert tilnærming. Interaksjonsdesignmetodikk er kombinert med tidligere forskning og teorier innen e.g. informasjonsvisualisering og situasjonsforståelse for å imøtekomme flygeledernes behov og sørge for sikkerhetstiltak. Den foreslåtte informasjonsgrafikken er implementert i en fullskala treningssimulator. Brukbarhetstesting i en mindre skala viste hvordan den nye grafikken er intuitiv og inneholder den nødvendige informasjonen. Ettersom teknologien utvikles bør det bli gjort mer forskning innen dette feltet, da særlig fokusert på hvordan man kan inkludere mer presis informasjon.

Executive Summary

Background

Cumulonimbus clouds (Cb) are one of the major hazards in aviation (Ahlstrom and Jaggard, 2010), but avoiding these dangerous clouds can be challenging. The Air Traffic Controllers (ATCO) have control over different airspaces and directs planes through these areas, affected by other planes and weather conditions. As clouds and their movements are difficult to predict or see exact on radars, warning pilots in advance can sometimes be challenging. ATCOs are often informed of Cbs by pilots who can see the clouds approaching. Together with Avinor and Edda Systems, IFE is working on the project ALMAR (A Large-scale Management of Air traffic control Research) to make aviation more efficient and safe, with the aim of using interaction design as a big part of this improvement.

Objectives

The aim of this thesis was to develop new information design for ATC, making it easier for ATCOs to perceive and understand relevant information about Cumulonimbus clouds, without demanding unnecessary attention, in Edda System's graphical user interface (GUI).

The Process

This master's thesis has had a user-centered approach in the development of weather graphic. Users have contributed through semi-structural interviews, focus group and touchstone tours as well as being objects of observations and test participants during the development process. As the user group is small and less accessible it became necessary to focus on qualitative data instead of quantitative, to make the most out of the few meetings and the users met. Empirical insight was combined with litterature to create a more holistic understanding of the ATC-world. Further, this was combined with theory on human factors and visual information in order to ensure necessary safety measures. Combining UCD with previous research has been emphasized throughout the project in order to accommodate possible safety measures in ATC environment, the user needs and create theoretical justifications. Thus, the theoretical part is recognized as decisive to this project.

Result
Field work and research describes Norwegian ATCO's work situation and needs. The thesis shows that limitations in the accuracy of weather information is seen as the biggest challenge in displaying weather information. However, it is questioned whether the existing display of weather information will be less suitable if technology improves. Further, the difference between Edda Systems' and the current graphical user-interface (GUI) is evaluated. As the GUIs are almost inverted in base color it is found necessary to develop a solution concentrating on Edda Systems' GUI, but with the aim of a generic solution. The design brief is focused around the communication of relevant information as well as the uncertainty of it. Acquiring the correct level of attention is emphasized in order to prevent creating dangerous situations by attracting focus to less important information. Additionally, making the solution adaptable to technological improvement is emphasized enabling development in coherence with the technology. The result is a proposed solution for graphical presentation of Cb in the Edda Systems' GUI, that visualizes uncertainty and two levels of weather intensity. An interactive prototype was developed to illustrate the emerging of the graphic in the system, and the solution tested in an ATC-simulator in cooperation with IFE.

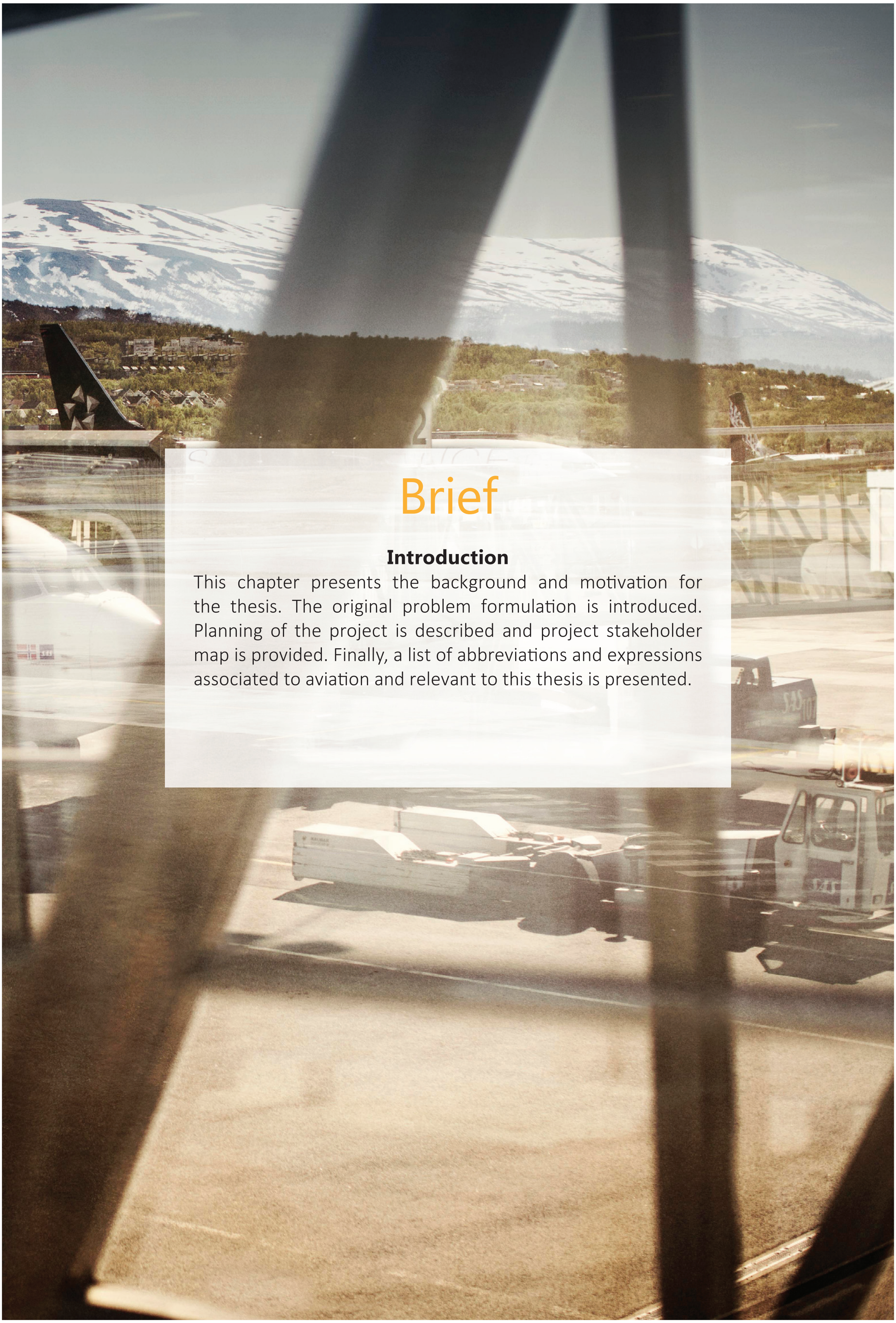
Delivery
Through a user-centered approach, this thesis provides thorough insight and analysis of Norwegian air traffic controllers' weather information. A proposed solution for graphical presentation of Cumulonimbus in Edda Systems' software, including an interactive prototype illustrating the animation of the solution. Further, two concepts are proposed to illustrate possible future upgrades in correlation with technological improvements.

Master thesis report
Attachment 1: Final solution in environment and statically illustrating animation. Digital and printed.
Attachment 2: Digital prototype illustrating animation.
Attachment 3: Two possible concepts based on future technological development. Digital and printed.

Content

This master thesis describes the process of the project done on presentation of weather information for air traffic controllers. Chapter 1 introduces the projects framework, collaborators and problem formulation. Chapter 2 explains air traffic control, its circumstances and future. Chapter 3 describes design methodology utilized in the project. In chapter 4, gained insight is presented and analyzed. While chapter 5-6 discuss the findings and focus, concluded by the Design Brief. Chapter 7 describes the development process, and chapter 8 presents the final result. Finally, chapter 9 provides evaluation on the solution and overall project.

Table of Content



Brief

Introduction

This chapter presents the background and motivation for the thesis. The original problem formulation is introduced. Planning of the project is described and project stakeholder map is provided. Finally, a list of abbreviations and expressions associated to aviation and relevant to this thesis is presented.

Photo: Avinor

1.1 Thesis Background

Motivation

Mostly having experience with interaction design through application development, I was intrigued by the idea of working with control panels and the challenges it includes. The demand of safety is an interesting aspect to the problem. Many people recognize Institute for Energy Technology (IFE) for their technological skills and academic environment for R&D on complex safety critical systems. I like working in the space between engineering and design, and saw it as a great opportunity to learn more and get a broader perspective on interaction- and information design. Further, experiencing how it is to collaborate with a more researched based environment was interesting as it is different from what I am used to.

Weather is an important factor in ATC. The problems regarding ATC are highly relevant and with possibly grave outcomes if not solved. This is what made this thesis so interesting to work on. In my earlier work I have mainly worked on more consumer problems. Focusing on a problem with more safety demands was exciting and motivating. I understood early that, due to a small and less accessible user-group and a somewhat conservative discipline as aviation is, this master thesis would challenge me finding suitable design methods.

Problem Description

Due to a parallel student project I was part of, the thesis completion had to be a few weeks earlier than normal. Because of limited time the problem description was, after consultation with Institute for Energy Technology (IFE), narrowed down to a quite specific area. The problem situation was specified to the challenges around Cumulonimbus clouds focusing on en-route and approach. Even though this is a quite concrete problem description, there are many different design challenges involving information, communication and interpretation.

Guidance

Associate Professor, Trond Are Øritsland, at Department of Product Design (IPD) has been my supervisor throughout the projetc. Further, Thomas Porathe, Professor of Interaction Design at IPD, have helped with additional guidance. Alf Ove Braseth, Dr. Philos at IFE, has been my external supervisor, my contact person at IFE and helped me in contact with other project stakeholders e.g. Avinor. I have also had good support in the rest of the ALMAR-team at IFE. Throughout the project we have had constructive dialogues on the process and result. I also sought input from other design-focused places, and was lucky to get guidance from Bekk Consulting AS. This was especially useful in order to find alternative methods to gain insight in an, to me, new discipline as aviation.

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Fakultet for ingeniørvitenskap og teknologi
Institutt for produktdesign

Masteroppgave for student Stine Marie Hjetland

Oppsett og presentasjon av informasjon for flygeledere

Layout and design of information for Air Traffic Control (ATC).

IFE er en selvstendig, internasjonal forskningsstiftelse for energi- og nukleærteknologi med om lag 600 fast ansatte. IFE er inndelt i seks sektorer, hvor Sikkerhet- Menneske- Teknologi-Organisasjon utgjør en av disse. Sikkerhet-MTO består av de tre avdelingene Industripsykologi, Programvareteknologi og Systemer og brukergrensesnitt. Avdeling for programvareteknologi har etablert forskningsprosjektet ALMAR (A Large-scale Management of Air traffic control Research) sammen med Edda systems og Avinor. Formålet er å bedre sikkerheten og effektiviteten i lufttrafikk-kontrollering. Forbedringen skal skje ved bruk av blant annet interaksjonsdesign gjennom å utvikle nye HMI (Human Machine Interface) løsninger for ATC. Interessante problemstillinger er faktorer som påvirker sikkerhet og effektivitet, en slik faktor er værsituasjonen. Enkelte værfenomener skaper problemer for avvikling av lufttrafikk. Endringer i omfang av ekstremværfenomener kan øke relevansen i dette. Arbeidshypotesen er at risiko i flytrafikken kan reduseres gjennom grafikk som informerer ATC om vanskelige vær-forhold.

Hovedfokuset i denne oppgaven vil være utfordringer rundt tordenvær (Cumulus/Cumulonimbus) i luftrom under flygning, samt under inn/utflygning (ikke under avgang/landing eller på flyplass). Oppgaven vil inneholde en kartlegging av nødvendig/ønskelig informasjon for de involverte aktørene. Ved hjelp av interaksjonsdesignsmetodikk vil fremstillinger av informasjonen bli utviklet og testet. Målet med oppgaven er å skape et konseptuelt design for oppsett og presentasjon av nødvendig informasjon til flygelederne (ATC). Formålet er å bedre sikkerheten gjennom økt situasjonsforståelse, dette vil også kunne forbedre effektivitet gjennom å støtte gode beslutninger og minke reaksjonstider.

Oppgaven vil blant annet omfatte:

- Involvering av flygeledere, piloter og andre viktige aktører
- Informasjonsinnhenting og analyse
- Utvikling av prototype(r) og gjennomføring av brukertester
- Konseptualisering av forslag til fremstilling av nødvendig informasjon for flygeledere

Oppgaven utføres etter "Retningslinjer for masteroppgaver i Industriell design".

Ansvarlig faglærer:	Trond Are Øritsland
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Utleveringsdato:	14. januar 2016
Innleveringsfrist:	9. juni 2016

Trondheim, NTNU, 14. januar 2016

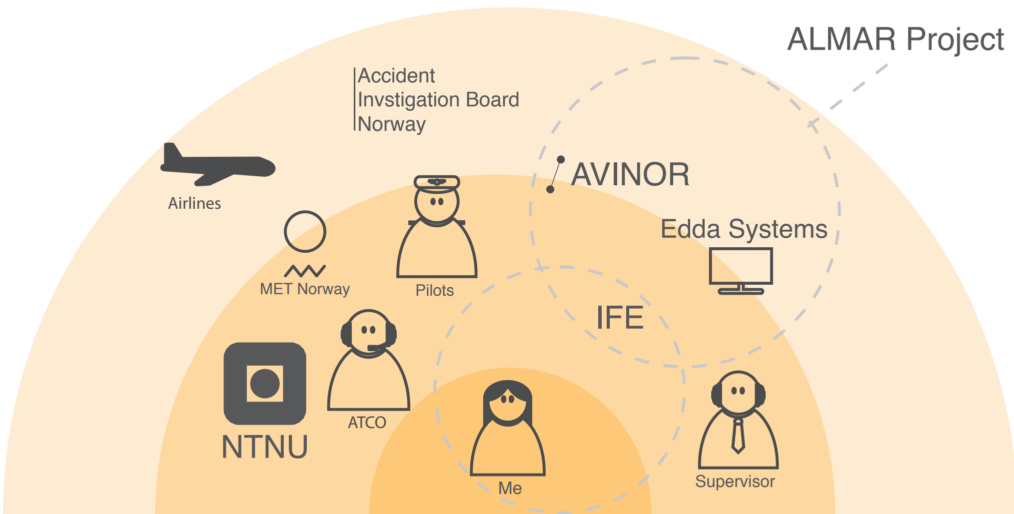
Trond Are Øritsland
ansvarlig faglærer

Casper Boks
instituttleder

1.2 The ALMAR-Project

About the ALMAR-project

The ALMAR-project, (A Large-scale Management of Air traffic control Research) is a cooperation project between IFE, Edda Systems and Avinor, established in 2015. The goal is to improve ATC, make it safer and more efficient. The improvement will, amongst others involve utilizing interaction design in the development of new Human Machine Interfaces (HMI) in ATC.



An illustration of the stakeholders I have had the most contact with during the project. Graded based on amount of contact. Stakeholder in the ALMAR-project is marked in the stippled, grey circle.

Institute for Energy Technology

Institute for Energy Technology (IFE) is an independent, international research foundation for energy and nuclear technology. The foundation is divided in to six sectors, and Safety Man-Technology-Organization (Safety-MTO), is one of these (IFE, 2016). Safety-MTO is divided into three departments: Industrial Psychology, Software Engineering, and Systems and Interface Design. Software Engineering is involved in the ALMAR-project and was my department of contact.

Avinor

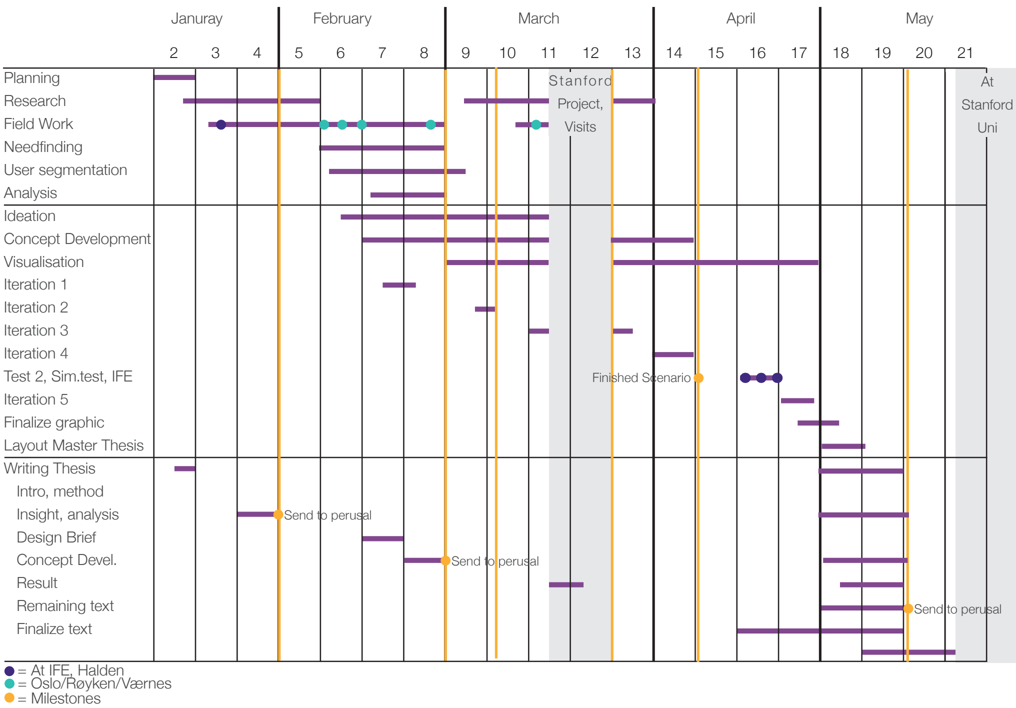
Avinor is a wholly-owned state-limited company. They manage and operate 46 of the airports in Norway. Through a subsidiary, the company educates air traffic controllers, runs ATC-services as well as necessary technical infrastructure. As a consequence, they are responsible for guidance and control of almost all air traffic in Norway. (Avinor,a)

Edda Systems AS

Edda Systems AS is a Norwegian company, specialized on ATC systems as well as tele- and data communication. Their main product is an ATC simulator called eCoach. Edda Systems AS emphasize operational experience and new technology in the development of their products. They have long experience with development, testing and commissioning of ATC systems (Edda Systems AS, 2010).

1.3 Planning

Because of the restricted time frame it was important to work evenly through the semester. Mapping out the whole process, and planning the project was crucial to accomplish in time. A Gantt diagram was created, to estimate the time spent. As such a process seldom is linear, the Gantt diagram was updated several times. However, it gave a good impression on how much time I had and could spend on the different tasks. Trying to structure the design process without limiting the creativity was interesting and instructive. To enable an easy way of looking back on the process, and document the development, an activity log was kept. The Activity Log can be found in Appendix.



1.4 Abbreviations

Abbreviations used throughout the text.

IFE	Institute for Energy Technology
ATC	Air Traffic Control
ATCO	Air Traffic Controller
APP	Approach, ATC-service
ATC TWR	Air Traffic Control Tower, ATC-service
ACC	Area Control Center, ATC-service (ACC)
Cb	Cumulonimbus cloud, weather phenomenon often associated with lightning/thunder.
METAR	Meteorological Aerodrome Report
TAF	Terminal Aerodrome Forecast
NATCON	Norwegian Air Traffic Control System, radar processing and display system
UFOV	Useful field of view
SA	Situation Awareness
LSM	Layered Scenario Map
GUI	Graphical User Interface


RWT
RWT
RWT

Methods:
Literature study
Interviews
Telephone/eMail

2 Air Traffic Control and Weather

Introduction

This chapter presents first the the discipline Air Traffic Control (ATC) and associated weather information. ATC is explained as well as what an air traffic controller (ATCO) does. Next, the weather phenomena Cumulonimbus (Cb) are described, how they occur and what makes them so dangerous to planes. Further, the existing weather information graphic for Norwegian ATCOs is presented, the challenges around the accuracy in weather information and its technological developments are explained. Finally, a short presentation of the developed solution is included. The insight presented is extracted mainly from literature research and databases, supplemented with information from field experts such as ATCOs, meteorologists, and analysts working in the Accident Investigation Board Norway (AIBN).

Photo: Avinor

2.1 What is Air Traffic Control?

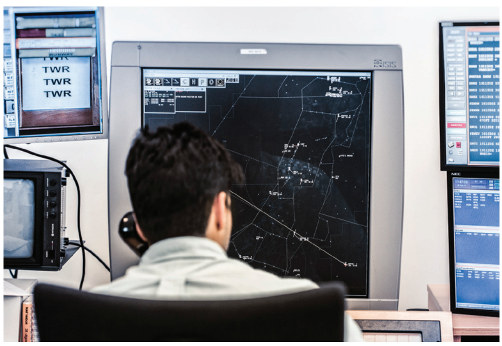
ATC is a ground-based service provided to control the air traffic efficiently, and maintain the safety in the controlled air space and on airports. The main purpose of the ATC is to prevent collision and other accidents, maintain the traffic flow and provide necessary information and support to pilots.

Airspace and Control Centers

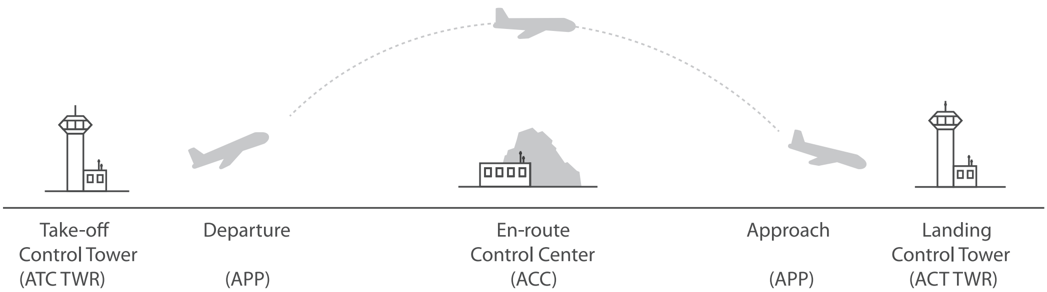
Norwegian airspace and large parts of the North Atlantic are controlled by Avinor's air traffic control (Avinor,b). In addition to local control towers at airports, there are ground based Area Control Centers (ACCs). In Norway there are three ACCs. They are based in Sola, Røyken and Bodø and control the southwest, southeast and north of the country, respectively. A flight is divided into take-off, departure, en-route, approach and landing, and ATC-services are needed in all stages. Take-off/landing is often controlled from air traffic control towers on the airports (ATC TWR). The ATC-service Approach (APP) can be delivered from the airport, or from a control center. The En-route-segment is controlled from the area control centers (ACCs). ATC TWR, APP and ACC are all controlled by ATCOs with some area-based specialized training.

2.2 What is an Air Traffic Controller?

Air traffic controllers (ATCOs) are the conductors of the air traffic. It is the ATCO's job to approve planes' movement and give directions, keeping the planes safely separated. They combine air traffic information with weather information to route planes safely through the air space they control. When hazardous weather occurs, such as the weather phenomenon Cumulonimbus, the ATCO assists the planes in avoiding weather, and approve re-routing. There can be local differences in procedures of conveying and handling weather avoidance (SKYbrary, 2014a). In congested airspaces the workload can change drastically when such weather have to be evaded (SKYbrary, 2014a).



An ATCO in work at his workstation. Photo: Avinor



Approach (APP): Service controlling a planes approach to an airports air space. Can be controlled from an ACC or a facility at the airport.

Air Traffic Control Tower (ATC TWR): Facility at airport from which ATCOs controls the traffic at and around an airport. Often placed in elevated towers at airports.

Area Control Center (ACC): Manned with ATCOs, controls the airspace between airports, which are not covered by the TWR or other APP-services.

En-route: When a plane is on its way, outside a control tower's air space.

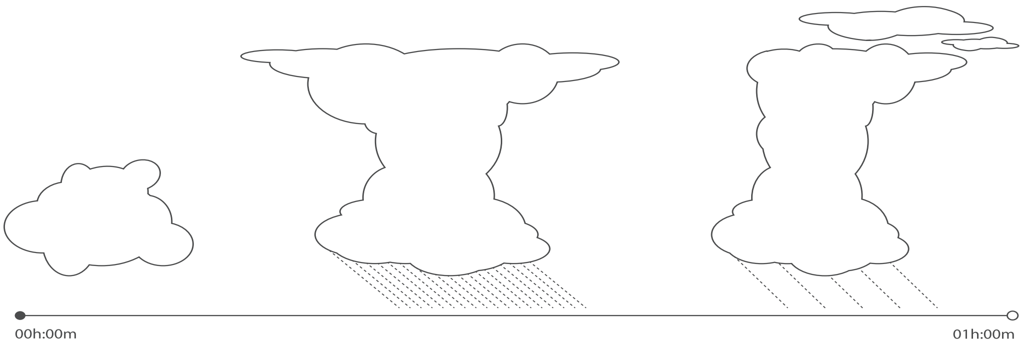


Illustration of a Cb's life cycle

2.3 Weather hazards and information in Air Traffic Control

Incidents

In 1985 a crash due to Cb-activity in Dallas, USA, made it clear how dangerous and unpredictable the weather can be. The accident investigation of the crash introduced training, equipment and information as important factors to avoid grave outcomes (National Transportation Safety Board, 1985). Even though precautions were made, incidents caused by weather still happens in Norway as well as in the rest of the world (Boeing, 2015, SHT, 2012a, SHT, 2012b, SHT, 2000). Weather is still a big challenge in aviation, as it cannot be controlled or completely avoided.

Cumulonimbus

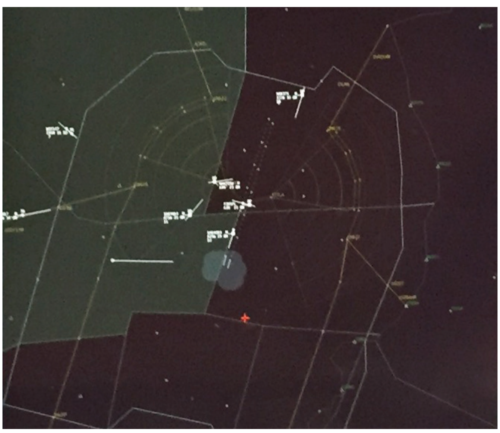
Of all weather phenomena, thunderstorms are the biggest contributor to aviation hazards and delays (Ahlstrom and Jaggard, 2010). Cumulonimbus (Cb) is one of ten different types of clouds (Halland, 2001). It is a precipitation- or thundercloud consisting of water droplets and crystals, often recognized by its anvil shape. This type of cloud can lead to strong turbulence, heavy precipitation including hail, icing, high risk of lightning and thunder and other extreme weather phenomena like severe downdrafts and tornadoes (SKYbrary, 2014b, Halland, 2001). Such challenges can have serious consequences e.g. the pilot loosing control over the plane, poor visibility, communication disturbances and physical damages to the plane (Halland, 2001). Thus, it should be avoided when flying (Halland, 2001).

A Cb can be hard to predict, but it is possible to register the conditions that can form these clouds (SKYbrary, 2014b). Weather forecasts, pilots' weather radar and pilots' view from the plane are important to uncover these clouds or identify the build-up of them. Halland (2001) explains how a pilot can evaluate the weather forecast based on what she can see from the plane, and further determine if there is any deviation from it.

By predicting the formation of a Cb, pilots and ATCOs can take necessary precautions in case they have to reroute the plane to avoid hazards, e.g. bring extra fuel, plan a new route. Sometimes the clouds can form a squall line which makes it difficult or impossible to go around. If so, the pilot might have to go off route by hundreds of miles to find the least dangerous way through the wall of clouds (SKYbrary, 2014b). A Cumulonimbus can have a duration approximately one hour (Meteorologisk Institutt, 2010).

Existing Weather Graphic

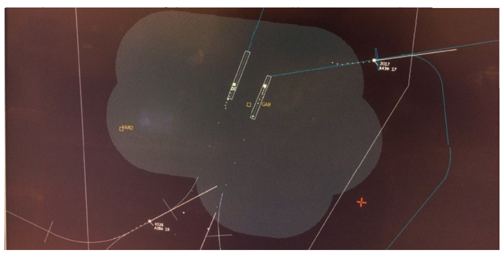
Today there is a graphical presentation of weather information in NATCON, Avinor's current air traffic control system. The graphic is on the ATCOs radar screen where a map of their airspace is displayed. ATCOs have the possibility to use a visualization of predicted clouds as an overlay on the map. Clouds, dependent on the sensitivity the software is adjusted to, are shown as unsymmetrical transparent overlay of white/grey. It can be perceived as if it illustrates the realistic shape of the cloud. The ATCOs opinion about the solution, and its graphics will be further described in chapter 4.



The exising weather graphic in the current software, NATCON.

Technological Development

Machines are taking over more and more of the human tasks within weather prediction. International research is done on how weather information can be gathered and handled. Next Generation Air Transportation System (NextGen) works towards new automation concepts including weather information. Further, research has been done on weather probe concepts to identify risky weather in aviation e.g. Automatic identification of risky weather objects in line of flight (AIRWOLF) (Ahlstrom and Jaggard, 2010). However, it is a concern that the machines do not have the same holistic view that of humans. Machines have trouble differentiating between fog, cloud cover or formation (Johansen, 2016), thus important information may be lost or misinterpreted. Prediction of clouds is complicated. Even though the technology improves, there might still be challenges that



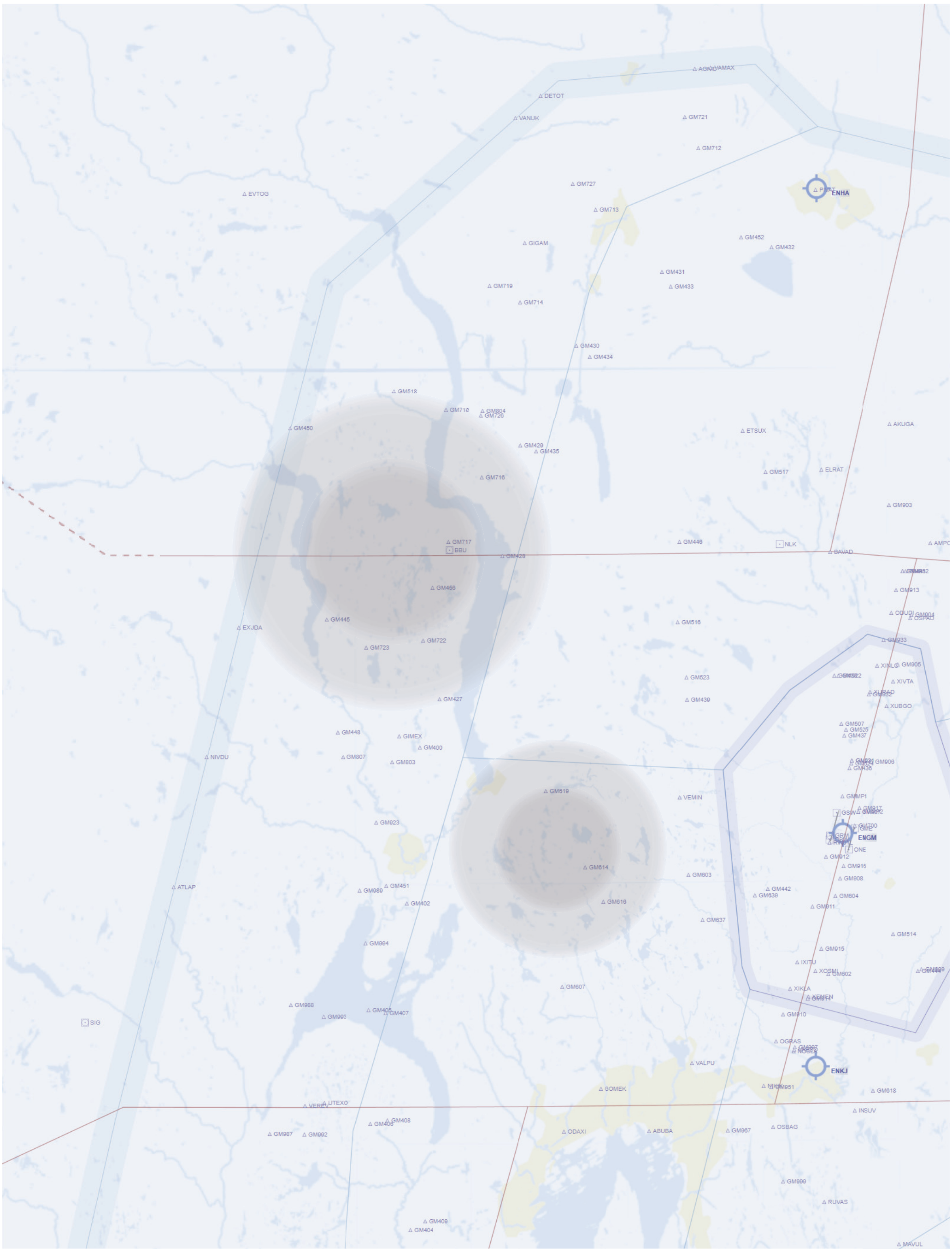
The exisitng graphic visualizing a cloud, or cloud-aktivity on the radar screen.

2.4 Introduction of Developed Solution: Weather Graphic

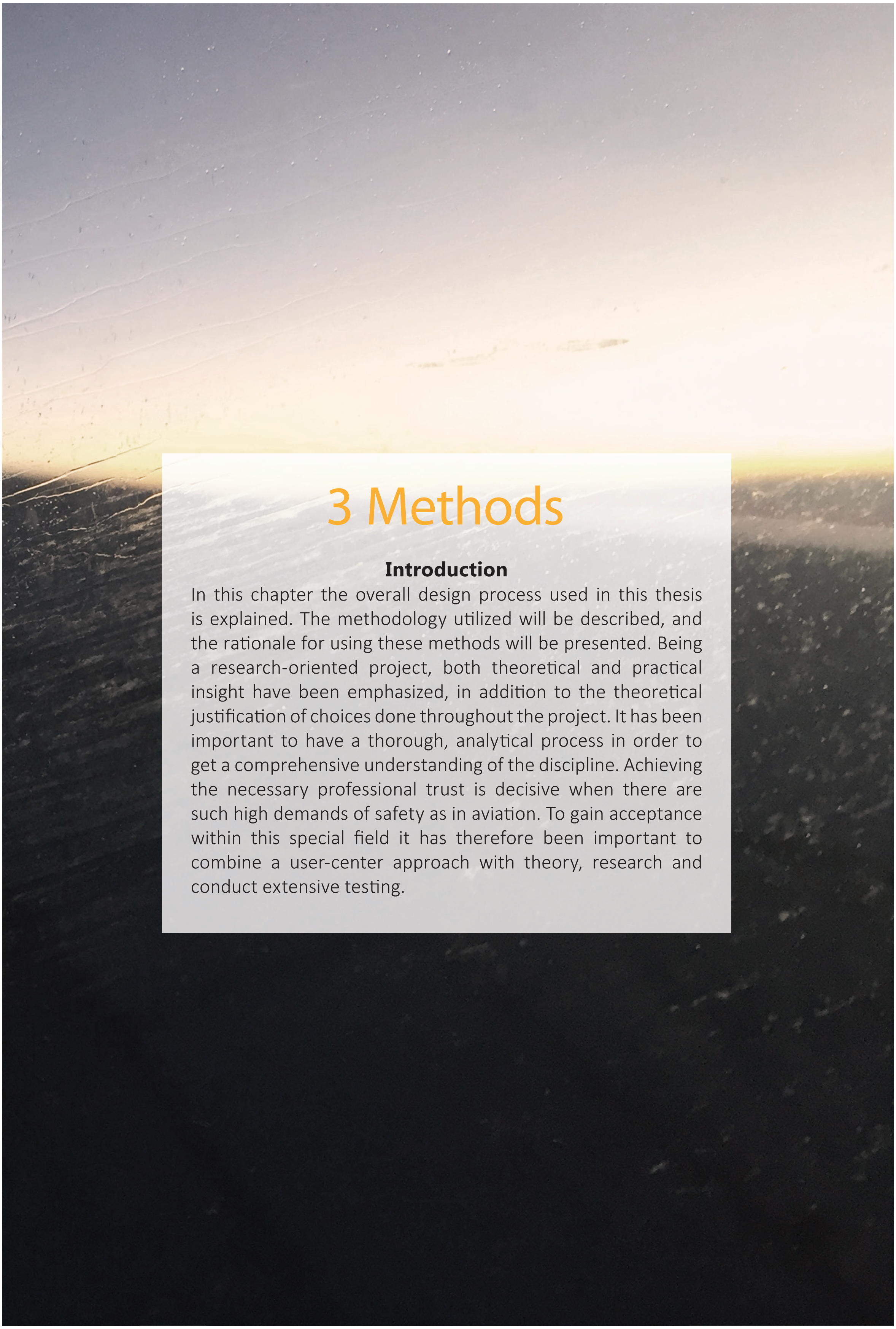
To give the reader an idea of the heading of this thesis a short introduction of the developed solution is included. A two-layered circular graphic was developed based on the combination of user insight, other fieldwork and theory found relevant. Due to limited level of precision in the weather information it was aimed at visualizing the uncertainty and indicating level of intensity. The circular shape, an unrealistic shape of a cloud, was one of the features used to convey uncertainty in order to make the graphic more honest.

The figure shows the final result. A two-layered Cb-graphic.

As illustrated on the next page, the graphic was tested in Edda Systems GUI. The picture illustrates how the radar screen would look in Edda Systems' training simulator for ATCOs. Both NATCON and Edda Systems GUIs were included in the developing process with the aim of making a generic solution. However, the GUIs being so different, this was challenging.



The figure shows the final result in context of Edda Systems' map, on the radar screen in their simulator.



3 Methods

Introduction

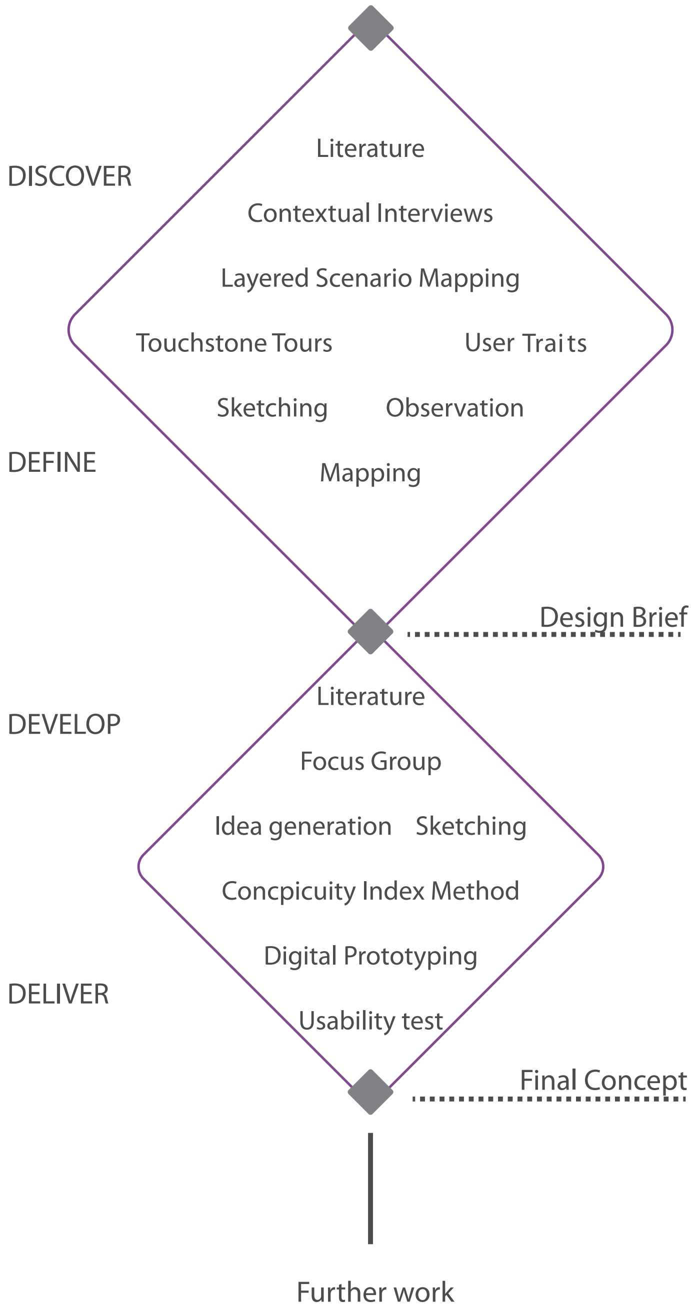
In this chapter the overall design process used in this thesis is explained. The methodology utilized will be described, and the rationale for using these methods will be presented. Being a research-oriented project, both theoretical and practical insight have been emphasized, in addition to the theoretical justification of choices done throughout the project. It has been important to have a thorough, analytical process in order to get a comprehensive understanding of the discipline. Achieving the necessary professional trust is decisive when there are such high demands of safety as in aviation. To gain acceptance within this special field it has therefore been important to combine a user-center approach with theory, research and conduct extensive testing.

3.1 Design Process

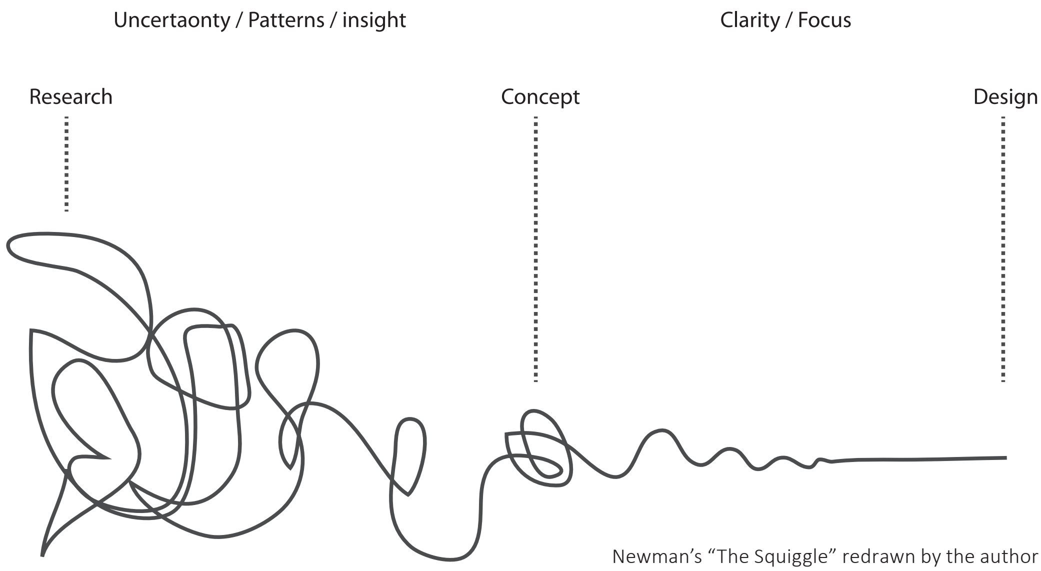
Double Diamond

In this project I have used the British Design Council's well known "Double Diamond" as the overall process guidelines. The Double Diamond, illustrated on the next page, divides the design process into four steps: discover, define, develop and deliver. The discover-part is wide. One wants to know as much about the problem as possible. Then, through analyzing the insight the problem scope is narrowed down and defined, which formulates the specifications in the design brief. Further, the development of a solution and the ideation expands again, this can help the designer develop a more complete and holistic solution. In the end, the solution is narrowed down through testing and evaluation and the delivery is completed.

I have used the Double Diamond as a guideline and moved freely within its frames, having an exploratory research approach to the discipline aviation. Thus, the design process has been iterative, with overlapping phases.



The British Design Council's Double Diamond, illustrated by the author and adapted to the project's process. Illustrates the overall process. It has been an iterative process, esecially wihin second diamond.

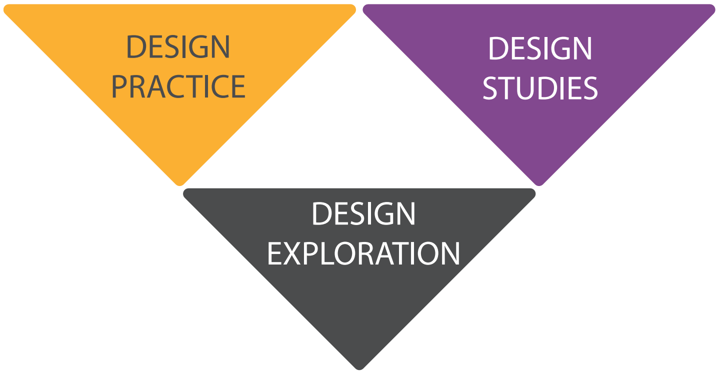


Newman's "The Squiggle" redrawn by the author

From The Squiggle to The Interaction Design Research Triangle

As shown by The Squiggle, illustrated above, a design process can be messy and complex in the beginning (Newman, 2010). Starting out, I thought this would be the most fitting approach to my project as aviation was new to me and I saw the need to be exploratory within the diamonds. Having a broad, iterative approach to aviation could be valuable in order to get a holistic understanding of the field.

Exploration takes time, and time is a limited resource especially when collaborating with others and their interests must be taken in to consideration. Even though it is important for the creativity to be free of too many constraints, it is an important balance between free creativity, field restrictions and time. Entering this project, I had some experience working with real customers and clients. However, no experience within a field of so many restrictions, safety wise and technical. Additionally, I had never before worked as close with external collaborators, which increases the demand for communication and planning. Thus, projects within this line of work are time critical, complex and safety relevant. The Squiggle would probably fit better in a more open, innovative and creative project, with less anchoring in a given task and constraints. The need of a more goal-oriented and propulsive approach emerged. Additionally, being able to tie the development and future design choices to theory and research would help increase the credibility of the solution.



The Interaction Design Research Triangle illustrated by the author. The figure will be recurrent in the thesis to give an indication on when in the process the different parts of the triangle has been emphasized.

The Interaction Design Research Triangle
To ensure progress and the necessary grounds of each step of my process I turned to Daniel Fallman's design research approach: The Interaction Design Research Triangle (Fallman, 2008). The triangle consists of the extreme points; Design Practice, Design Studies and Design Exploration. Simply put, the three can be perceived as skills and experience, academia and theories, and creative thinking and what if?'s, respectively. Thus, Design Practice is the skills a designer has built up working as a designer on other projects. Design Studies are design theories, relevant literature e.g. information visualization and graphics when working on information design. Design Exploration means challenging boundaries and looking to the future. What exists and what is possible?

Fallman encourages moving between the three corners of the triangle in order to get the best result. Combining practice, academia and exploration enables a more controlled iterative process within these fields, as one can trigger the other. It can be natural to think that such a multi perspective approach can help develop the solution in a broader perspective. It also ensures validity by triangulating between theory, practice in user domain and creative design intervention. Combining my experience with research and academia (the experience of others) will create a good base of knowledge for the solution. Further, exploring and challenging this knowledge concurrently, can help the project move forward.

User-centered design

User-centered design (UCD) is a broad term describing a design process where the end-users are included in some way, e.g. as informers, testers, co-designers (Abras et al., 2004). As this project evolved around developing a solution for one particular expert user group, it was natural to have a UCD-approach. This is something I have broad experience with through my studies. Endsley and Jones (2012) presents UCD as a process starting in the opposite end than technology-centered design. While technology-centered design starts with what technology you have, its possibilities and limitations, UCD look to the user capabilities and needs. When the user-interface adapts to the operator it reduces errors and improves effectivity (Endsley and Jones, 2012). My task was to develop a solution for an already existing system, thus, it was important to adapt to the people

"(..) the vast majority of your user research should be qualitative – that is, aimed at collecting insights to drive you design, not numbers to impress people in PowerPoint."
- Nielsen (2011)

operating it. As I came to learn through my insight phase, air traffic control is, as so many others, an occupation with routines. In such environments, change can be frightening and difficult to adapt to (Jacobsen, 2012). Including the user in the developing process will not only make the solution more user friendly. It can increase the chance of developing something that is more easily implemented in a well-established work environment.

Qualitative method

Having a UCD-approach and a limited user-group made it necessary to use qualitative research methods. However, aviation is a conservative business where quantitative data are more respected when communicating findings and reasoning design choices.

It was desirable to have some quantitative insights to uncover diversity and tendencies within the ATCOs field of work, but it was difficult to conduct as my time with the end-users often was restricted. A qualitative approach to gather data from the users I met was therefore prioritized. However, as I was alone when gathering qualitative data I was afraid I unconsciously would affect the information e.g. through my note taking or interview technique. In an attempt to ensure diversity in insight and interpretation I teamed up with four third grade students who were also working on ALMAR on a project on wind data for air traffic controllers. Together we visited Værnes airport and conducted mapping-workshops, shared knowledge and insights. Having someone with knowledge within the same field who could challenge my opinions, and whom I could discuss with was valuable. It made the output of the qualitative research more thoroughly processed and analyzed.

Resources

For domain- and user-insight I have observed and interviewed different actors within aviation in Oslo, Røyken, Halden and Trondheim. With help from IFE and Avinor I have been able to meet and visit end-users and other people within aviation on different locations of interest. I have also been able to use my private network to get in touch with other stakeholders such as pilots.

For design- and process related input I have had guidance from Bekk Consulting AS, classmates and professors at the Institute of Product Design, NTNU in addition to my supervisors.

20.01. Touchstone Tour, Edda Simulator
IFE, Halden, (ALMAR-team)

06.02. Observation & Interview
Cockpit SAS, Trondheim - Oslo, (2 pilots)

09.02. Observation, Interview, &Touchstone Tour
ACC Røyken, (ATCOs, supervisors, other)

15.02. Observation & Interview
Cockpit Norwegian, Oslo - Trondheim, (2 pilots)

22.02. LSM Workshop
NTNU, (4 Students)

25.02. Observation & Interview
Værnes APP/TWR, 4 (ATCOs, supervisors)

29.02. LSM & Mapping Workshop
NTNU, (4 Students)

03.03. Phone Calls
Accident Investigation Board Norway and
Civil Aviation Authority Norway

17.03. Focus Group
Værnes APP/TWR, (3 ATCOs)

11.-14.04. Conspicuity Test
NTNU, (5 participants)

21.-22.04. Formative Usability Test
IFE, Halden, (4 ATCOs)

24.05. Master Finished
NTNU

09.06. Master delivery
NTNU

17.06. Master presentation
NTNU

Timeline giving an overview of where and when different methods has been utilized.

3.2 Choices of Methods

Different methods utilized in the project are described bellow, as well as why the method was chosen, and how it was implemented. Additionally, the utilized methods are listed on the top right on every new section.

Even though the project is within the fields of interaction- and information design, methods from service design have been utilized as well. This is quite common, as interaction- and service design have overlapping methodology, particularly in the beginning of a project. Well-known design methods such as observations, prototyping and details of usability testing are not explained below, as it is assumed that the reader has a basic knowledge of design methodology. The methods used where chosen based on my experience from studies, research, guidance from supervisors and other professionals.

WHAT KIND OF METHOD?

WHY THIS METHOD?

HOW THE METHOD WAS IMPLEMENTED?

INSIGHT AND ANALYSIS

Following is the methodology used in field work described, as well as ways of analyzing and handling the information. Insight and Analysis represent the Discover and Define parts of the Double Diamond. The different corners of Fallman's Interaction Design Research Triangle utilized is marked in each subsection throughout the report.

Literature study

A literature study is a study of existing literature and existing research e.g. books, papers, articles. It also covers internet search but with high demands to the sources credibility (Martin and Hanington, 2012).

A literature study is an easy way to learn about a new field of study. To get a grasp of aviation, the cloud phenomenon Cumulonimbus (Cb) and other relevant subjects early in the process and later as an additionally research phase, a literature study was a fast way to gain knowledge.

I searched for scholars on the internet using technical terms e.g. ATC, ATM, Situation Awareness, METAR, TAF, weather radar, Cumulonimbus. In addition to scholars and regular internet search, I read books in airplane psychology, meteorology (Halland, 2001, Myhre, 1993), human factors (Endsley and Jones, 2012) and aviation reports from the Accident Investigation Board Norway (SHT, 2012a, SHT, 2012b, SHT, 2000) to inform design choices and validate against theory. This prepared me with basic insight before the field work, and improved my understanding in my further work. It also uncovered important aspects to keep in mind during the concept development, such as situation awareness. Other design literature utilized regularly throughout the project was Stickdorn et al. (2010), Ware (2008c), Ware (2004), Martin and Hanington (2012), Lidwell et al. (2003), Tullis and Albert (2008), Tufte and Weise Moeller (1997).

Secondary literature

This is a kind of literature study only wider and not as strict when it comes to its sources. It covers magazines, forums, blogs and other channels and can be a supplement to the literature study.

As ATCOs mainly can be reached through scheduled meetings, contact with them was limited. To learn more without meeting them face to face, I found them on the internet. Of course it is limited what is actually available on the internet, but there are blogs and forums where ATCOs discuss everyday struggles. These sites can help give an understanding of the user group. As Lurås (2012) put it: "But if you don't have the chance to meet the users "in the wild", you can learn a lot from meeting them online".

I used the internet to find ATC forums and Facebook pages in attempt to get insight about the user. There are a few ATCO-blogs (Watson, 2015, Chambers, 2016, Farley, 2016) which can create a picture of what kind of people ATCOs are. However, it is important to keep in mind that it can be a certain kind of people who starts these blogs. I found more international blogs and forums than Norwegian. Since there are national differences within ATC, international information must be used more as pointers and indicators than facts on how ATCOs are. This applies to this type of literature in general.

Contextual, semi-structured interviews:

Contextual interviews are interviews with the user in the relevant environment, where the service/product will be used. Semi-structured interviews allow a more conversational dialog, opens for detours within the subject. However, the interviewer often has a list of subjects or topics that she want to address during the conversation situations (Martin and Hanington, 2012) (p.102).

To gain insight about the work of air traffic control from the ATCOs perspective. ATCOs are handling a great amount of equipment. Conducting interviews on their work station made it easier for them to explain how things work. It also creates a natural environment to talk about work related things, and it was clear that the people found it relaxing. Keeping the interview semi-structured is an easy way to keep the dialog going and opens up for more information than what you already know you need information about. It can help uncover information gaps you do not know exists.

During the project I visited the Air Traffic Control Center (ATCC) in Røyken, Værnes Tower/Approach control (TWR/APP) at Værnes airport Trondheim and sat in cockpit on two approximately one hour flights. All visits were combined with interviews and observation. Different people were interviewed: ATCOs, supervisors, pilots, and former ATCOs. The duration of the interviews varied based on the need of information, from 10 minutes up to one hour. It was very useful to get insight on the work situation the ATCOs are in, as well as it was to see the pilots side of the situation. Based on information from the ATCO it was clear that the communication with the pilots was important. Seeing and hearing both sides of this point of contact gave a greater understanding of the need of information and possible challenges.

From cockpit on flight Trondheim - Oslo

Touchstone Tours

A guided tour in the user's environment, where the user facilitate, explains and share their world. An important aspect was that the person observing takes an active part, and can interrupt, point and ask questions to create a broad understanding of the system (Martin and Hanington, 2012).

To quickly immerse in the world of the user. The method let the designer see the current environment, with relevant equipment, users in work situation (in this case) and ask questions. Thus, enhance the understanding of the users world. As the ATCOs workstation is complex, touchstone tours was a way to get the most out of the visits.

Touchstone tours was utilized in the beginning of the project in the insight phase. First as guiding through the IFE's ATC-simulator, experiencing and learning how it works, and later at Røyken ACC and Værnes TWR/APP learning more about the ATCOs workstation.

Information gathering through telephone calls and eMail

Calling or sending an email is more distant, limited and structured ways of gathering information. It was in this case utilized to get answers from specialists within different disciplines. Sending questions in an email let persons of interest respond when they can, and also gives them time to think their answers through. Thus, it can lead to more ideal answers. It is important to formulate the questions with this in mind. Looking for facts in this approach might be better than wishing for the honest opinion.

Trying to reach meteorologist and specialists in the Accident Investigation Board Norway (AIBN) and Civil Aviation Authority Norway can be challenging, as they are busy people with no relation to the project. A phone call or email are less demanding than scheduling a meeting face-to-face.

Contact information to relevant people was found through internet search on MET Norway and AIBN's webpages. The different persons were first called to establish the contact, then a follow-up email was sent. In some of the cases the telephone calls turned into casual interviews, or an email dialogue started if the person contacted was open for further questioning.

User Traits

User traits is a way of presenting the user, and uncover user needs. It is based on information from e.g. interviews, observations. Knowing e.g. age, educational level, work experience helps adapt a solution to the user (Nielsen, 1994).

User traits was chosen as presentation method of the ATCOs to accommodate the user needs without getting to personal. As it was the need of the employees that was interesting, user traits was decided more fitting than e.g. personas. Focusing more on the need of the role than the person behind it. Creating a broad picture of the ATCO role could help see the superior needs at work. During the insight phase it became evident that ATCOs are different, even though it is a specialized job. However, focusing on more personal factors and differences did not seem as important, as the employees enter the role as an ATCO when at their workstation.

Based on conducted interviews, observations and literature studies information about ATCOs was gathered. Further, ATCO is a specialized profession and Avinor have a list of traits a possible applicant should possess.

Mapping of context

It creates an understanding of points of contact and interactions through conversation and observation in the given environment. A methodology used in both interaction design and service design. (Stickdorn et al., 2010)

To better understand the situation the interaction design will be used in, with opportunities and challenges. Experience the environment around the person interacting with it, and discover how new interaction design can help the situation. Mapping e.g. communication and stakeholders in relation to each other helps understand the work situations.

Based on insight from interviews, observations and touchstone tours, information- and communication flows was mapped out. Sometimes in cooperation with ATCOs to make sure the information was correct. Thus, it was also used as a communication tool to help mutual understanding.

Layered Scenario Mapping (LSM)

Layered Scenario Mapping (LSM) is a technique used to map out the situation one designs for. It is a systematic approach to organize information from an overview, down to situational details. Additionally, the LSM can be used together with the user to easier uncover misunderstandings and gaps in insights (Lurås, 2015).

LSM was developed by Lurås (2015) during an offshore project. There are many similarities in the challenges between an off-shore- and an air traffic control-project. In both cases, it is often a new discipline to the designer with a lot of information and technical details. In information rich projects it can be demanding but important to understand the discipline, environment and user quickly. Systematizing information and seeing different parts in relations to each other is valuable and increases the understanding.

A Layered Scenario Map is usually implemented a bit out in the process to structure collected insights. However, during this project two LSM was created. One in the beginning (LSM I) and one further out in the process (LSM II). LSM I mapped out an ATCO's shift. It was conducted as a preparatory workshop with the four bachelor students, doing the project on wind data for air traffic controllers, as a way of sharing knowledge, uncover blank spots, formulate questions and create a curious mind-set before meeting the users. Later, this map was reviewed and corrected based on the new insight. Further out in the project LSM II was created to map out a Cb-situation. Both LSMs was used as communications tools with ATCOs and also validated this way.

	EN-ROUTE	RADAR SENSING CB
What happens	Flying through airspace	Weather radar sense possible Cb-activity approaching.
Actors involved	● Pilot/Copilot ● ATCO	● Pilot/Copilot
Communication	Face to face ●←→● Radio ●←→●	Face to face ●←→●
Equipment used	Autopilot Weather Radar Radio	Weather Radar
Information needed	Weather Information, Traffic information, Clearance to travel through airspace	Intensity of weather Precipitation Elevation, extent Turbulence
Functionality needed	Possible radio contact with ATCO	Access to weather radar and its sensitivity
Critical Point		

Illustration of the different categories a Layered Scenario Map can be divided into. The rest of the map can be seen in chapter 4.6

CONCEPT DEVELOPMENT

This section presents the methods used to gain feedback from users, and test possible concepts during the concept development. The Concept Development is in the develop and deliver parts of the Double Diamond.

Focus Group

ⓘ

A focus group is a small group of carefully selected people who deliberate and discuss e.g. a solution or a trend (Martin and Hanington, 2012) (92).

?

A feedback session with a focus group was carried out early in the development phase to create an open dialog with the users. Focus groups enables the designer to listen to discussions and reflections regarding different concepts, it opens for a dialog where more insight about the users can be acquired.

The focus group consisted of three operative ATCOs of different age and experience. Printed digital sketches were introduced to the group. First on the screen background they are used to, then on Edda Systems background, in order to first test the graphic without the ATCOs being affected by the new background. The participant could discuss the different solutions, occasionally a question would be asked in order to keep the dialog going.

"Supposing is good. Finding out is better."

– Mark Twain

Conspicuity index method

ⓘ

Alexander Wertheim introduced the conspicuity index method in 1989, based on the belief that an objects visibility is affected by the context it is in. The conspicuity is defined when an object is masked by its surroundings, viewed peripherally. As the conspicuity index increases, the chance of spotting the target increases when focusing within the radius of the conspicuity angle during the search process. Porathe and Strand (2011) found the method to be a useful tool for designers within information design, based on a study focusing on signs.

?

The conspicuity index method is a low-resolution test that quickly can give an idea of the visibility of an object, and help exclude or sort possible solutions.

Four different digital sketches were tested, They where picked based on the feedback from the focus group and relevant theory. Five people, with normal or corrected to normal vision, conducted the test. Porathe and Strand (2011) discuss whether or not a big group of participants is necessary, as trends in the test results often are evident after testing only a few people.

Formative Usability Test

Testing of realistic solution implemented in Edda Systems simulator.

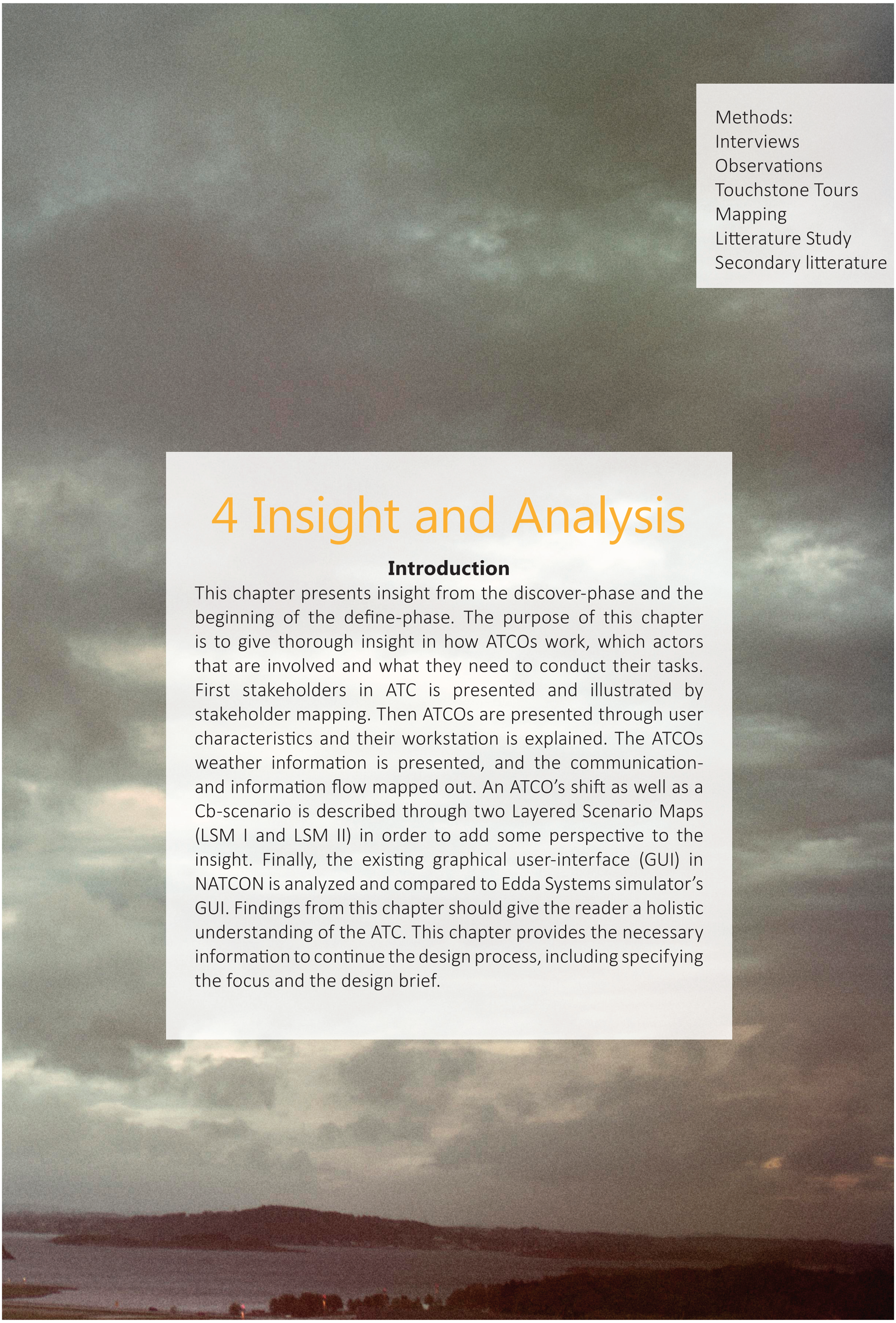
A formative usability test is a usability test conducted by a specialist within the topic. Tullis and Albert (2008) compare the test with a chef evaluating, preparing and improving a dish. As the chef, the specialist, evaluates and improves the solution, based on her professional insight.

A formative usability test was conducted to uncover possible design improvement. Testing the specialists (ATCOs) in an simulated work situation to provoke possible semi-realistic problems, and thus uncover possible problems.

Four operative ATCOs was tested in Edda Systems' simulator in IFE, Halden. The participants worked as ATCOs in the simulator, where the Cb-graphic was implemented and introduced. The ATCOs executed two scenarios, 10 minutes each, with adjusted work load to enable them sharing their thoughts while working. To conclude the test a 10 minute semi-structured interview was conducted, including the ATCO evaluating how they perceived the proposed solution based on four factors, serious, safe, useful and truthful.

Ideally more people would have been tested in the conspicuity test and the formative usability test. However, Jakob Nielsen state that in qualitative tests it is often sufficient with around 5 participants as it is enough to reveal the main usability problems (Nielsen, 2006, Nielsen, 2012). Thus, a qualitative test with four participants would probably be enough to uncover indications of severe usability problems.

Participant conducting the Conspicuity index method test.



Methods:
Interviews
Observations
Touchstone Tours
Mapping
Litterature Study
Secondary litterature

4 Insight and Analysis

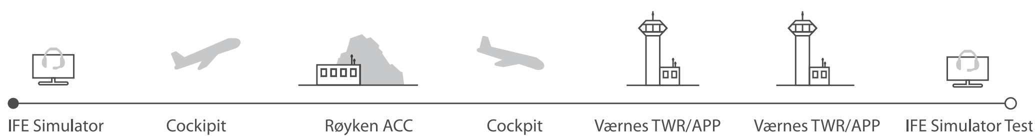
Introduction

This chapter presents insight from the discover-phase and the beginning of the define-phase. The purpose of this chapter is to give thorough insight in how ATCOs work, which actors that are involved and what they need to conduct their tasks. First stakeholders in ATC is presented and illustrated by stakeholder mapping. Then ATCOs are presented through user characteristics and their workstation is explained. The ATCOs weather information is presented, and the communication- and information flow mapped out. An ATCO's shift as well as a Cb-scenario is described through two Layered Scenario Maps (LSM I and LSM II) in order to add some perspective to the insight. Finally, the existing graphical user-interface (GUI) in NATCON is analyzed and compared to Edda Systems simulator's GUI. Findings from this chapter should give the reader a holistic understanding of the ATC. This chapter provides the necessary information to continue the design process, including specifying the focus and the design brief.

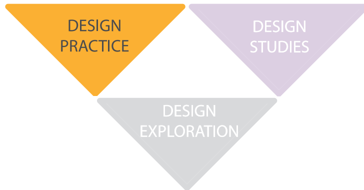
Photo: Avinor

4.1 Grounds

The information presented in this chapter is based on interviews, observations and touchstone tours done at Røyken ACC, Værnes TWR/APP, and in cockpit during flight. Additional information about Cb is based on telephone interview and mail correspondence with MET Norway and aviation meteorologists, as well as literature studies.

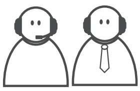


Timeline, from January to April 2016, showing my meet-ups with ATCOs and other stakeholders.



4.2 Stakeholders

This subsection describes the different stakeholders in ATC and their relation to ATCOs. The stakeholders where mapped out based on insight from literature studies, meeting people within air traffic control and interviews with ATCOs. Others than ATCOs also play important parts in how information are perceived or conveyed in ATC. Below, the different stakeholders are described.



ATC: Operator and Supervisor
The ATCO has the executing role within ATC as the operators. On every shift there are a few supervisors, in addition to all the ATCOs. The supervisor's role is to have the overview of all the air spaces their section is covering as well as adjacent airports or ATC-units. They are handling general information about weather or incidents, and have direct contact with their ATCOs. An example could be if Oslo Airport, Gardermoen, has to be cleared for snow, the supervisor would make sure all the ATCO are informed. Throughout this text the operators are referred to as the ATCOs, and supervisors as supervisors. However, both roles are included in the work within ATC.

Pilots
Pilots are some of the main users of ATC services and play an important part of the ATCO's work day. The pilot get route clearance and re-routes from the ATCO based on the traffic and weather. The pilots can influence these decisions a great deal as they often know about interfering weather before the ATCO. The pilots can see e.g. building clouds and bad weather rising, inform the ATCOs about this, and request re-routing around bad weather. If that is the case, the ATCO trusts the pilots weather information more than the weather information they have on their own systems. Additionally, the planes are equipped with weather radar, which will be examined later in chapter 4.5. Thus, they have more accurate weather information than the ATCOs. Even though the pilot can see parts of the Cb, this type of cloud can be bigger than what the pilot can register. Due to the anvil shape, hail that falls from the top of the cloud can appear to fall out of clear sky.

Based on findings from interviews the pilots are usually pleased with the way ATCOs control the traffic. However, they agree on that it in some cases would be easier for them if the ATCOs saw the same picture as they did, through the window and on their radar screen, as it would simplify communication and coordination. Oral communication enables possible misunderstandings, even though they emphasize that it does not happen often.

Norwegian Meteorological Institute, Aviation Weather Service

Norwegian Meteorological Institute (MET Norway) conduct meteorological services for the Military and Civil Services in Norway, as well as the public. The Aviation Weather Service is part of the public services MET Norway provide. The service operates from the surveilling offices in Oslo, Bergen and Tromsø, from the military aviation weather offices in Bardufoss, Bodø and Ørland, and from Longyearbyen.

MET Norway provide the ATCOs with weather forecasts called METAR and TAF (see further explanation in chapter 4.5). One of the biggest challenges for the Aviation Weather Service is to deliver enough and as accurate information as possible to both civil and military users. It is challenging to predict weather with high accuracy due to technological challenges and limited resources. MET Norway also provides pilots with weather forecast prior to flights, as part of their flight planning.

Airline

Airlines operate many different routes domestic and international. They travel through airspace of many nations. Flying via Norwegian airspace is preferred by many airlines, as it is less expensive than other airspaces. Thus, a planes route is planned not only based on its destination but also which airspace it is flying through. Airlines can choose to fly around a country because the air traffic control service there is expensive.

Avinor and national authorities

The Norwegian ATCOs are employed by Avinor Flysikring AS, a wholly owned subsidiary of Avinor AS, which is under the Norwegian Ministry of Transportation and Communications. Avinor operates under national and international legislation, and is overseen by Civil Aviation Authority of Norway (Luftfartstilsynet). Thus, Avinor wants the ATCOs to conduct their work in a way that is cost-saving and safe, following all agreements and regulations. Running a cost efficient business lowers the prices of the service and can increase the air traffic (hence income) as the airlines choose to fly through Norwegian air space.

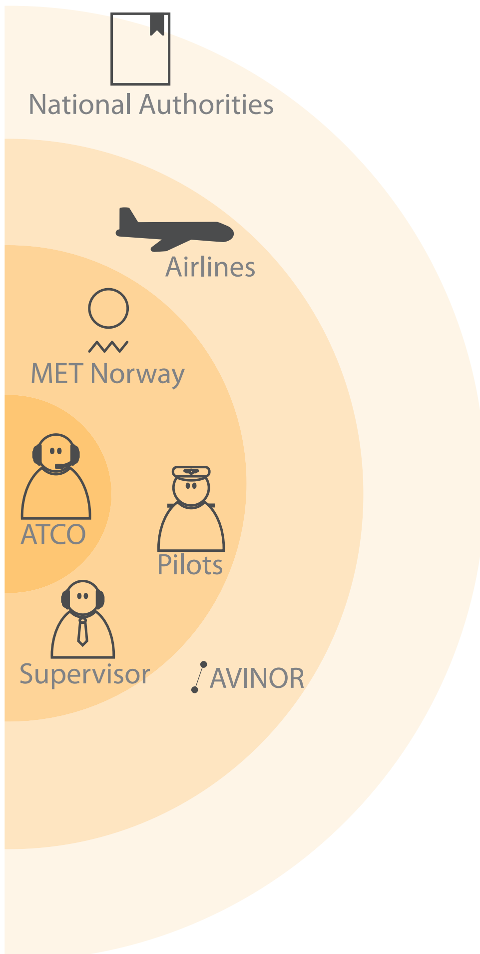
Stakeholders: Needs and Opportunities

Needs

- Efficient and safe traffic handling. Shorter routes equal less fuel, time and money spent.
- Clear communication between ATCOs and pilots.
- ATCOs need technological improvements for weather information.
- Pilots might need Cb-information on many altitudes, due to the Cb's anvil shape.
- Solutions and equipment that does not require replacement often. As implementation and testing demands time and money.

Opportunities

- Communication between ATCO and pilot has improvement potential.
- Pilots provide ATCOs with more accurate information.
- Precise weather information can reduce flown distance during rerouting (reducing fuel, cost and time).



Stakeholder map. The closer the stakeholders are to the ATCO, the more contact they have.

4.3 Meeting the ATCOs

This section introduces the ATCO further. The process of becoming an ATCO is described, the people working as ATCOs is introduced through user characteristics and their opinion on how todays visual presentation of Cb-information .

Insight about the users was gained through interviews, observation, literature studies and secondary literature. ATCOs are a group of expert users, that are limited in number, and can be hard to get hold of. Thus, additional literature is valuable. As ATCO is a profession, there is great variation in personality of the employees. However, there are some common characteristics, as it is a specialized job and it is a comprehensive and challenging process just being accepted to the study.

ATCO-Admission

To become an ATCO you have to have an unblemished record, be at least 19 years old, and be in possession of general admission with minimum requirements of grades. Furthermore, there are several screenings to pass before you are evaluated as an applicant. In the preliminary screening different abilities are tested: concentration, multitasking, space perception, decision making, stress tolerance, team work, and apprehension. The admissions is affected by the results from the preliminary tests and an individual evaluation of the applicant's qualifications and personality. If you fail to be accepted, you do not get a second chance. As a newly employed ATCO you have a yearly income around 570 000 NOK (Avinor, e).

User characteristics

Through Avinor's requirement site for ATCOs, other webpages directed towards ATCOs and social forums, they are perceived as a fairly homogenous group. Avinor characterize ATCOs as someone who is focused, analytic, self-conscious, reliable, creative and communicative (Avinor, c). After interviewing ATCOs, their supervisors and other people working in the same environment it was clear that even though ATCOs have to have certain types of skills and personality features, they operate differently. Reactively or planned was mentioned as a way of identifying the internal differences in the group. This could vary based on experience and personal preferences.

After interviewing the ATCOs, it can be argued that there is a lot of pride in handling the job. When asked what they do if unexpected information is given, the repeated respond was "I just remember it!" or occasionally that they might wright it down. "Just remembering" was talked about as common sense, you just do it. ATCOs are solution oriented. "I just fix it" was their explanation of how they solve problems and conduct their tasks. There are lots of invisible tasks and tacid knowledge, something new ATCOs have to pick up along the way.

To ATCOs it seems like there is no problem that can not be solved. Things might not be perfect, but they make it work. The same goes for weather information.

ATCOs about Cb-clouds

ATCOs want more precise information to better handle the air traffic, and avoid Cbs. They often wait for the pilot to inform about weather conditions and request re-routes, as they have more accurate weather information. If Cb-activity is reported of in an area, the ATCO inform other incoming flights to make them aware of the conditions. Potentially, having Cb-activity in your air space can lead to increased re-routing and vectoring (Vectoring is a work methodology used by ATCOs to give headings and estimate routes). Even though the ATCOs are aware of Cb-activity it is difficult to predict how a pilot want to be re-routed, according to the ATCOs it can depend on the pilot's preferences, and the type of the airplane.

"New people get used to it after a short time. It works fine".

– ATC Supervisor, Røyken ACC.
About unwritten rules of ATC.

"You do not want to send a plane into a Cb"

– ATCO at Værnes TWR/APP

"It would have been nice to have more accurate weather information. (..) But it is not so!"

– ATCO, Værnes TWR/APP,
about the provided weather information.

Today there is, as mentioned in chapter 2, an existing solution for visualization of weather information on the ATCOs map, NATCON. However, according to the ATCOs the amount of utility varies. It is used to get an idea of how much weather it is, thus they can be mentally prepared if pilots starts asking for re-routes. The ATCOs impression is that this information is unprecise. Some turn it on and off during the shift maintaining the understanding of how it might be out there, others only look at it in the beginning of their shift. They do not trust the information alone, and reports from pilots are valued and trusted more. However, after observing and interviewing relevant stakeholders it showed that many of them felt todays visualization solution worked fine. The ATCOs is used to the way it is.

Further, the uncertainty in the information provided was referred to as the problem, not the graphic. However, no one protested against a possible upgrade of visualization or information, as long as it would not disturb them or draw their attention away from more important things than the weather, e.g. colliding airplanes.

ATCOs are standing in front of a paradigm shift. Avinor are amongst others working on remote control towers, thus, the job tasks will change (Avinor, f).

ATCOs: Needs and Opportunities

General

- ATCOs are solution oriented
- Takes pride in controlling and handling their profession
- Uses NATCON solution to maintain understanding of possible weather development
- The ATCOs trust weather information from the pilot more than their own information.

Needs

- A solution that does not challenge or change their way of working
- Improved accuracy of weather information
- A solution that does not take away attention from more important things
- ATCOs need to know about uncertainty of information

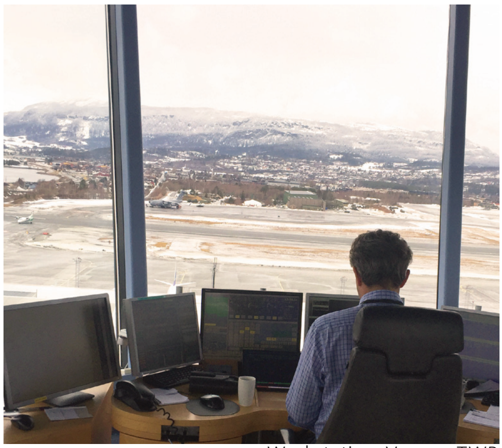
Opportunities

- ATCOs might be more open for a change as they are not pleased with parts of todays solution of weather visualization
- The ATCOs remember a lot of information. Even though they mean it works fine, what happens the day something goes wrong, if something is forgotten?

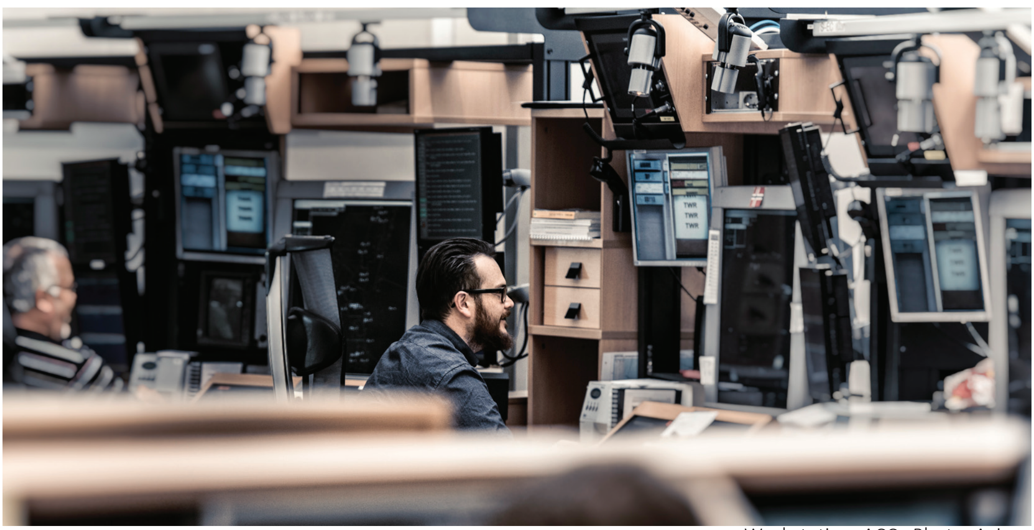
4.4 The ATCO's Workstation

This subsection describes and explains the ATCOs workstation in order to give an understanding of the work environment the ATCO operates in.

There is one workstation for each ATCO on shift. The ATCO's workstation varies based on location, but they do have some common main equipment. The difference in the work environment is bigger between the ATCOs in the towers and the ATCO in the ACCs. The ATCOs working in the towers have the office with the best view, whereas the ACC ATCOs are sitting inside a control central with no outdoor view.



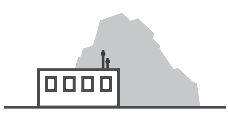
Workstation, Værnes TWR



Workstation, ACC . Photo: Avinor

ACC, Røyken
In Røyken ACC the room is divided based on geographical sectors. Visiting Røyken ACC it might seem like they are working on systems that have not followed the technological evolution. To an outsider it looks like they have not changed much, only replaced papers with screens in some cases. The whole system and layout show signs of development bit by bit and not in coherence. Due to safety matters ACCs are often thoroughly secured. As Røyken ACC where the room the ATCOs operates in is placed inside a mountain, with no windows.

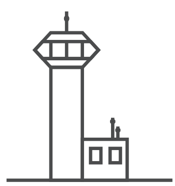
TWR and APP, Trondheim airport, Værnes
At Værnes the TWR control is placed in the top of the tower, and APP is placed further down in a different room. Thus the workstation of an ATCO varies based on where she works, en-route, APP or TWR, as information is more or less relevant for the different control areas. The tower control can for example use their outside view to read the weather. As they use the view as a tool, the workstation is adapted to this. However, the main equipment is the same for ACC, APP and TWR.



ACC ground based control center.

Equipment
There is a lot of information to take in and control. Despite internal differences, all ATCOs mainly have three screens. One for weather information and other traffic information (RANDIS), one radar screen displaying a map over the air space they are controlling and the planes within it (SDD), and one screen displaying airplanes arrival (AMAN), as illustrated on the next page. In addition they have small paper strips for each plane they are controlling. The strips contains relevant information for that plane e.g. flight number, route/altitude, re-routing and other information the ATCO finds relevant.

Many ATCOs have a note pad where they write down information, if they do not just remember it in their head. At Værnes TWR/APP this notepad has been formalized as a scheme that are passed on to the next shift.



TWR control is placed in the top of the tower.

Workstation at Røyken ACC

RANDIS:
Weather information and traffic information is presented in short or coded messages on the screen.

SDD:
The radar screen displays a map of the relevant air space. NATCON is the software providing the maps. The screen show all planes as small squares, plane labels provides necessary flight information.

AMAN:
Arrival manager, displaying airplane arrivals helps the ATCO coordinate and plan.

Workstation: Needs and Opportunities

Needs

- Most ATCOs needs help to remember information (notepad)

- ATCOs need to keep their information flow as simple as possible as their workstation presents a lot of information on different formats. Changes should be easily integrated in the workstation and not add more channels for the ATCO to respond to

Opportunities

- The radar screen is one of few things that is consistent wherever the ATCO works. Developing for the main equipment (eg. radar screen) decrease the need of adjustments due to internal differences

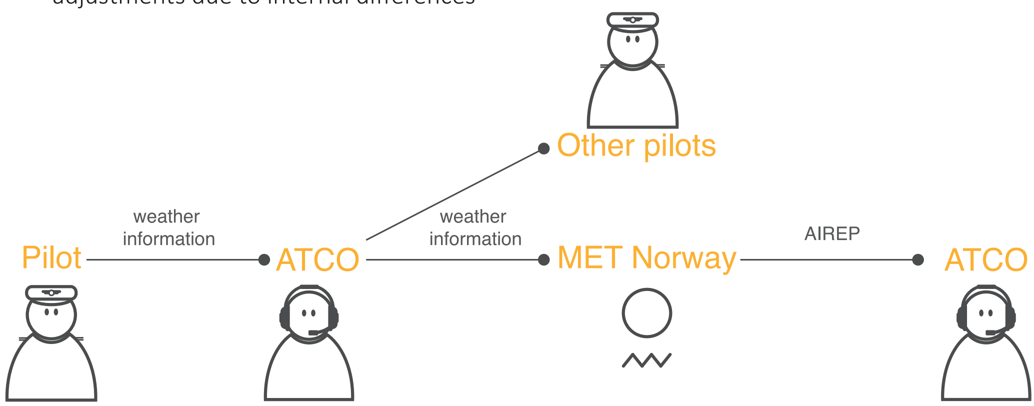


Figure illustrating how an AIREP is created. See further explanation on next page.

4.5 Provided Weather Information

This subsection presents the weather information ATCOs are provided with. In addition to the graphic overlay in NATCON on the radar screen, ATCOs get weather information from other equipment and sources as well. Following, the additional information from MET Norway is presented. Further, pilots equipment is introduced in order to explain how they can provide more accurate information to the ATCOs. The purpose of this section is to inform the reader of how ATCOs are informed about Cbs in the airspace.

Weather Information from MET Norway
The ATCOs working in ACCs have the biggest disadvantage when it comes to weather information. Due to lack of visuals to the airspace they control, their need of additional weather information is severe.

The ACC ATCOs uses weather reports, information from airports and radar to get the information they need to control their air space safely.

METAR is routinely weather observations provided every hour or half-hour from airports or weather observation stations. It is a coded message on e.g. wind, clouds, precipitation, temperature.

TREND is provided within the next two hours if there is need for added information or the weather changes.

TAF is a short, coded approximately 24 hour forecast that is provided approximately every 6th hour.

AIREP is weather information provided by pilots, via ATCOs to MET Norway, and back to the ATCOs again. If a pilot observe Cbs, she informs the ATCO who further informs MET Norway. MET Norway writes the AIREP, which appears on RANDIS back at the ATCO's screen.

Weather information like METAR, TREND,TAF and AIREP is provided on RANDIS.

Weather radar in cockpit

The airplanes cockpit have weather radar. Based on which sensitivity the pilot adjust it to, it show clouds and their density. The radar shows the strength of the weather by color-coding. Green being small clouds with no precipitation (again, this is affected by the adjusted sensitivity of the radar) further the colors yellow, orange, red and purple follow. Where purple is the worst. The weather radar are often more accurate than ATCOs weather information, however, it can not be trusted blindly as the radar signals can be “swallowed” in the Cb, and give incorrect results on the radar screen. Also, the radar only shows the front of the weather, not cross-sections.

Weather radar in cockpit

Weather Information: Needs and Opportunities

Needs

- Need a solution that can present information despite inaccuracy.
- Correct and honest visualizations. If there is an uncertainty, it should be apparent.

Opportunities

- Using AIREPs as a source for the graphic prediction. The ATCOs trust and listen to the pilots, and AIREPs are based on information from pilots.
- There are established colors to indicate weather intensity.
- New ways of predicting weather in aviation are being researched.
- Parts of the technological development is challenging e.g. prediction of clouds. Thus, the need of more accurate information might be further in the future.

4.6 ATCOs in Context

In this subsection different situations and relations are mapped. The information presented above is put in relations to each other in order to give a more thorough understanding. During the project this mapping was used as a communication tools to validate the insight acquired. Thus, they have been discussed with ATCOs. First, the information and communication flow is mapped out to illustrate connections and relations. Then a ATCOs shift is mapped out and explained with the use of Layered Scenario Mapping. Following is a Cb-situation illustrated. Actions, communication and equipment utilized is put relative to each other, in order to show functionality and purpose.

Communication flow

ATCOs are in contact with different stakeholder in multiple ways during their shift. The figure to the right is a simplified illustration of who is in contact and how, during an ATCOs shift.

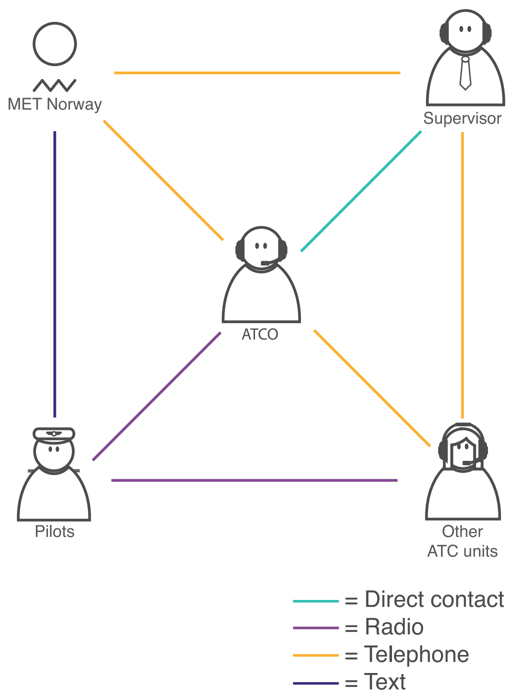
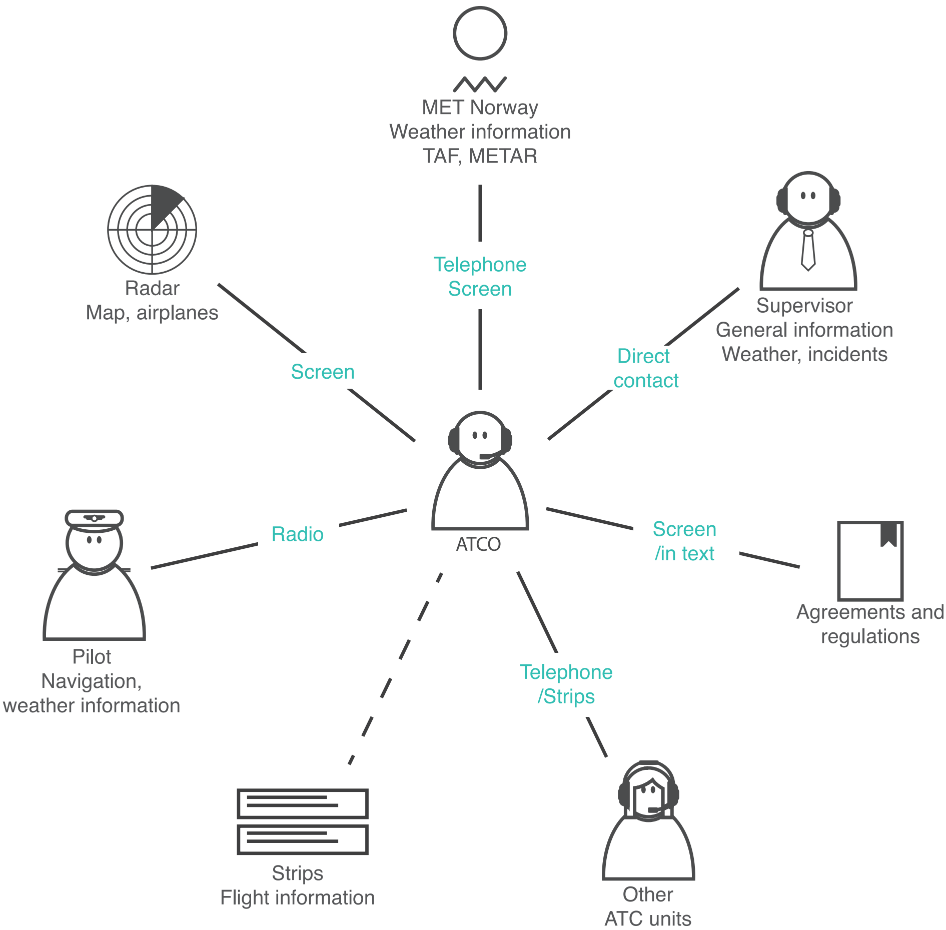


Illustration of communication flow



Information flow
During their shift the ATCOs are exposed to a lot of information through different channels. As seen from their workstation there are multiple screens, radio, paper sheets etc. The figure above illustrates the different information provided to them, and how It is provided.

Layered Scenario Mapping

The following four pages presents two layered scenario maps (LSM) developed during the project. LSM I illustrates an overview of typical tasks during an ATCOs shift, regarding weather. LSM II illustrates a Cb-scenario.

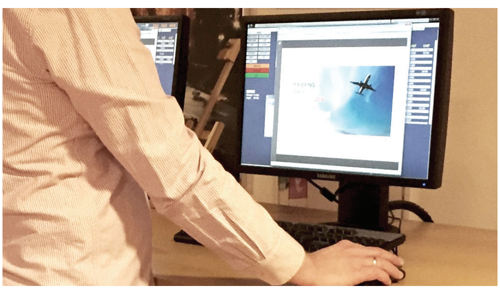
Layered Scenario Map I (LSM I): An ATCOs shift

The shift of an ATCO normally lasts about 2 hours, which is recommended as a maximum. Before the shift starts the ATCO have to go through a pre-briefing. Røyken ACC and Værnes TWR/APP operates with different pre-shift briefing stations. However, they are overall providing the same information e.g. weather information, different TAFs, important occurrences. Every shift overlaps with 10-20 minutes, giving the new ATCO time to establish a situational understanding. Relevant information is provided orally or written on the notepad.

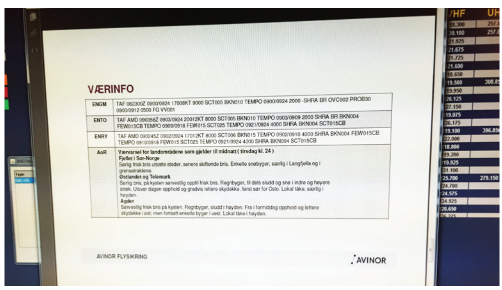
Layered Scenario Mapping (LSM II): Cb-Scenario

When a Cb occurs it can affect the routing of the traffic. Especially if it is at particular places, such as approaches and other pre-defined routes. As it is understood that ATCOs operate differently it is difficult to predict exactly how such a scenario is executed. However, there are some common factors.

In this scenario the pilot informs the ATCO about the Cb. Based on interviews, this was the most common scenario. Unless the ATCOs have very accurate information about Cb-activity in a certain area, they wait for the pilot to inform them where it is. When the pilot become aware of the Cb the ATCO is informed.



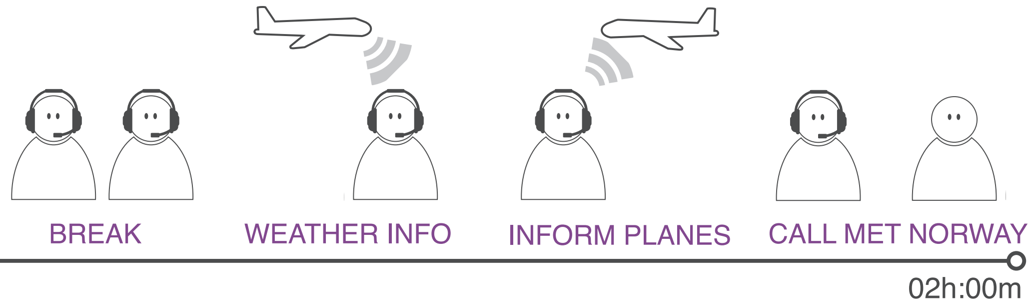
Briefing station at Røyken ACC, before entering the work area.



Picture from the briefing station. Exemplifies how weather information is provided and presented on screen.

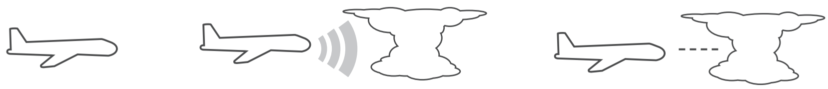
Layered Scenario Map I (LSM I): An ATCOs shift
Information found to create an understanding how a ATCOs shift is carried out. As there are internal differences this LSM only represent the overall storyline of a shift.

What happens	Pre-Shift Briefing	Take over a shift, from ATCO1 to ATCO2 (15 - 20 min)	Start working, gaining situation awareness
Actors involved	ATCO2	ATCO1 ATCO2	ATCO2
Communication		Face to face	
Equipment	PC and external screen/Printed documents	Notepad RANDIS, NATCON, Strips, Radio	Notepad RANDIS, NATCON, Strips, Radio
Information needed	Weather and generel information: METAR, TAF, incidents	General and Extraordinary information	Information on weather and planes, incidents
Functionality needed		Memory	Memory, sort information based on relevance and importance
Critical Point		ATCO1 forget to provide ATCO2 with all relevant info	

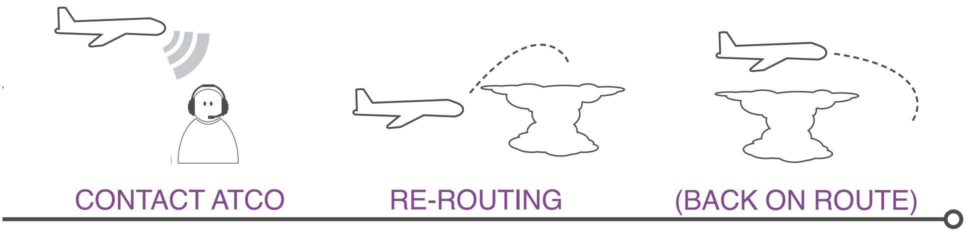


Break e.g. leaving the desk due to toilet break	Recieve weather information from pilot	ATCO2 inform other pilots about weather conditions	ATCO2 inform MET NO of important weather info. Met NO creates AIREP
ATCO2 ATCO3	ATCO2 Pilot	ATCO2 Pilot2	ATCO2 Met NO
Face to face ⟷	Radio ⟷	Radio ⟷	Tele ⟶
Notepad RANDIS, NATCON, Strips, Radio	Radio (Notepad)	Radio (Notepad)	Telephone
Information on weather and planes, incidents	Orientation, altitude, placement, precipitation	Orientation, altitude, position, precipitation	e.g. orientation, altitude, position, precipitation
Double all functions needed when working.	Memory Notepad	Memory Notepad	Memory Notepad
ATCO2 forget to provide ATCO3 with all relevant info, or vice versa when ATCO2 returns	Misunderstand or do not hear given information. (Does not happen often)		

Layered Scenario Map II (LSM II): Cb-Scenario
Mapping of how a cb-scenario can unfold.



	EN-ROUTE	RADAR SENSING CB	(SEEING CB)
What happens	Flying through airspace	Weather radar sense possible Cb-activity approaching.	(Possible visual confirmation on Cb-activity. Informs ATCO)
Actors involved	Pilot/Copilot ATCO	Pilot/Copilot	Pilot/Copilot
Communication	Face to face Radio	Face to face	Face to face
Equipment used	Autopilot Weather Radar Radio	Weather Radar	Windows Weather Radar
Information needed	Weather Information, Traffic information, Clearance to travel through airspace	Intensity of weather Precipitation Elevation, extent Turbulence	Intensity of weather Precipitation Elevation Turbulence
Functionality needed	Possible radio contact with ATCO	Access to weather radar and its sensitivity	See the clouds, and precipitation Feel possible turbulence
Critical Point			



Contacts ATCO inform of weather condition and re-quest re-routing	Re-routes based on clearance from ATCO	If not done in advance: Pilots contact ATCO to get clearence on getting back on the originally route
● Pilot/Copilot ● ATCO	● Pilot/Copilot	● Pilot ● ATCO
Radio ● ⟷ ●	Face to face ● ⟷ ●	Radio ● ⟷ ●
Radio Weather Radar	Autopilot Weather Radar Radio	Radio
(Cb-activity) Possible re-routes	General Weather Information, Traffic information	Traffic information General Weather Information,
Access to radar sensitivity Radio contact	Possible radio con-tact with ATCO	Radio contact
		!! Possible misunder-standing. Entering back on route before clearance

Situations and Relations: Needs and Opportunities

Needs

- ATCOs already handle many points of contact. It should be prevented adding any more points of contact or channels to respond to.
- Cb information is not crucial. It should not take unnecessary attention.
- ATCOs needs briefing to create necessary situational understanding.

Opportunities

- The contact between pilot – ATCO – MET Norway is established.
- What if the ATCO can be proactive, and re-route and plan re-routes before the plane make contact? A way of working more efficient?

4.7 Radar Screens: Graphical User Interface

In this section the actuality of changing the radar screen's graphical user-interface (GUI) is explained. NATCON's and Edda Systems' GUI is presented and compared. As the new weather-information solution will be implemented and tested in Edda Systems' software this is the GUI that is emphasized. However, as NATCON is the system the ATCOs are working in today it should be taken into account. As the two GUIs are very different it was seen necessary to examine both and compare them. Thus, be aware of big differences that can affect the feedback from user through discussions and testing. As ATCOs are used to NATCON it might be valuable to use its GUI in parts of the development process. Thus, the change would not be as radical.

Actuality

March 31st 2016 Avinor announced the decision of investing in a new air traffic control system (Avinor, 2016). Thus, replace the existing system, NATCON. One of the big problems with NATCON is the limited graphical freedom. According to the ATCOs, layers and gradients get pixilated in NATCON. An upgrade of the system might help improve the graphical quality and further the graphical user interface. Due to the cooperation with Edda Systems, IFE had already chosen a different map background than the standard NATCON displays. As Avinor changes their collaborators, it increases the possibility of a more radical alteration in the future, such as renovating the map. Such a change demands thorough testing of e.g. ATCO's endurance when working on a brighter screen than before.

NATCON, Todays Radar-Screen

NATCON can be adjusted based on personal preferences. This is typical for such radar screens as the ATCOs have to stare at them constantly. Previous research show that the personal adjustments to the screen can affect the quality of the information provided on the screen, and following affect how the information is perceived (Ahlstrom and Arend, 2005). As the background and other graphic can vary between ATCOs, developing new graphic can be challenging.

Map

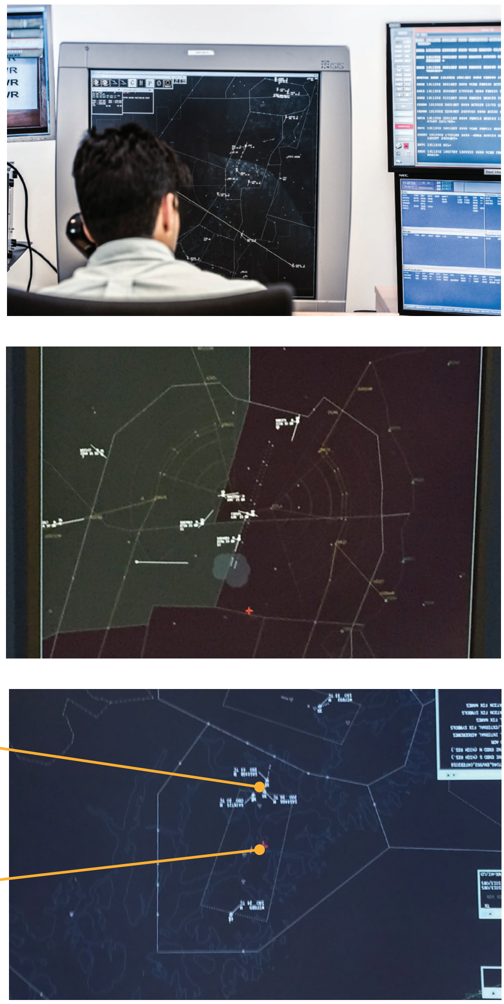
The map in NATCON is dark, almost black with few details. There are often only borderlines in a brighter shade of grey that are marked. Further there are fixed points in brighter colors marking routes or set points. The amount of details is often based on experience. As more experienced ATCOs often turn it off when they have learned the static details of the map.

Planes

Planes are grey, with a vector as direction indicator and a label with flight information.

Other graphical elements

Other graphical elements and marks on the map are in bright grey. A few symbols are marked in color often because of higher importance.



Sections of NATCON maps. The upper picture illustrates how it is arranged at an ATCO's workstation. Photo: Avinor

Edda Systems and IFE simulator

The GUI described is the version implemented in Edda Systems' and IFE's simulator. Because some elements where missing from the GUI these elements where made by IFE, in order to enable testing.

Sections of Edda Systems' map. The upper picture show how a part of the simulator was arranged.

Map

Edda System's map is closer to original maps and much brighter than maps in NATCON. The base color is bright grey on land, and blue to indicate lakes etc. As in other air traffic control maps it is possible to adjust the screens brightness and colors after personal preferences. The map has sharp edges and lines. The borderlines are bright blue or red, depending on the type of border.

Planes

IFE have designed their own labels in Edda Systems' simulator. The labels are grey and white, rectangular boxes with blue text.

Other graphical elements

There are much more details on Edda Systems map. Approach lanes are marked in bright blue, other route points is also marked in different shades of blue. Marking of other airports is grey asymmetric areas

ATCOs about NATCON

Even though it is possible to adjust the GUI based on personal preferences, it is not practiced a lot. The main difference is that some more experienced ATCOs turn of geographical features and approach lanes because they know them by heart. The ATCOs turn off all information found unnecessary in order to keep their screen clean. Further, the ATCOs mentioned that compared where the technology is today NATCON has poor resolution, which limit the possibility of graphical means.

Radar Screens, GUI:
Needs and Opportunities

General

- As Edda Systems already have a lot of color it can be disturbing or messy to introduce more colors.

Needs

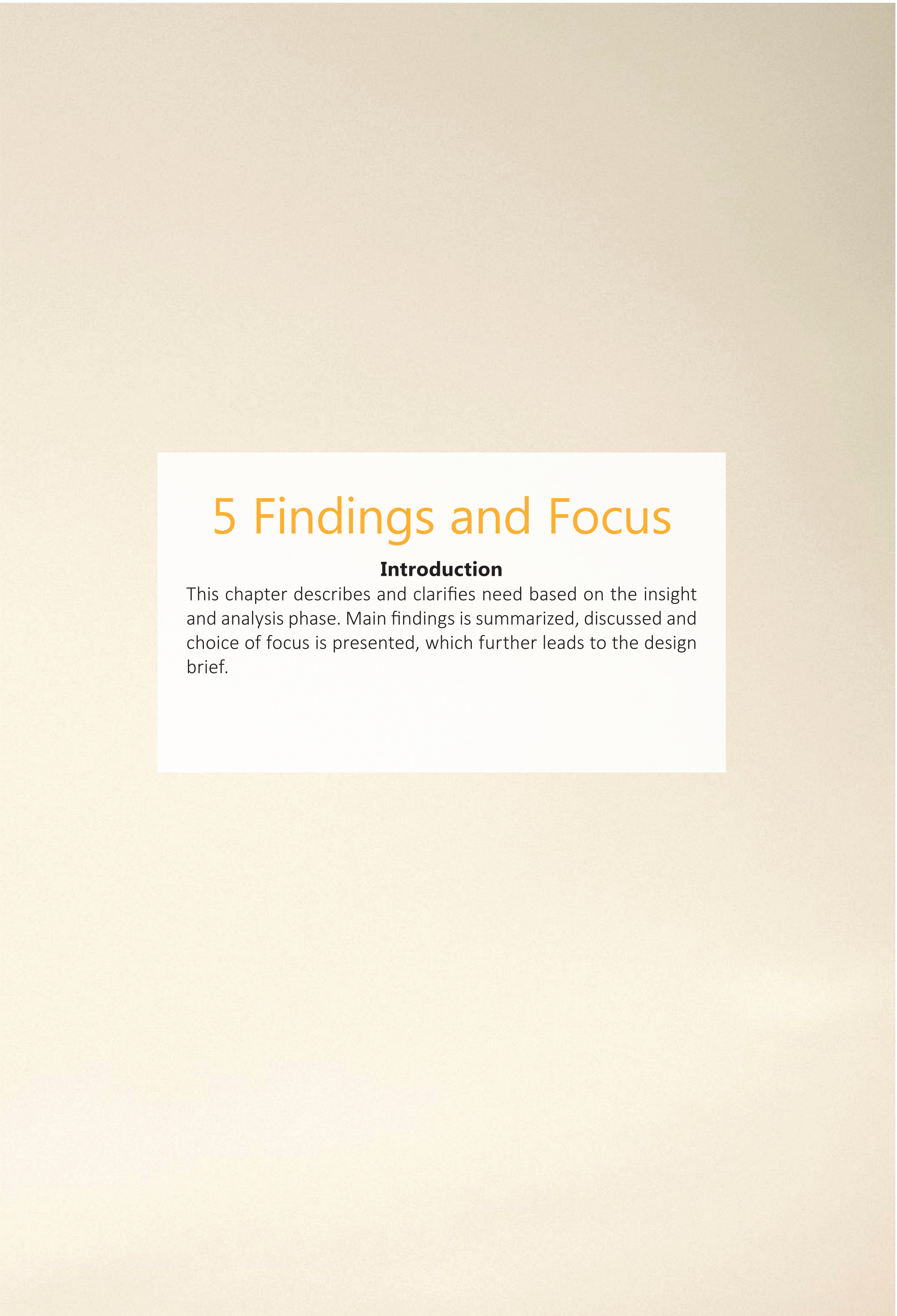
- A solution should take into account that parts of the GUI, e.g. color, contrast, might vary based on personal adjustments.

Opportunity

- ATCOs are used to graphic weather information on their screen.
- Both maps has characteristic sharp lines and edges.


ATCOs at the workstation. Photo: Avinor

Photo: Avinor



5 Findings and Focus

Introduction

This chapter describes and clarifies need based on the insight and analysis phase. Main findings is summarized, discussed and choice of focus is presented, which further leads to the design brief.

Photo: Avinor

5.1 Clarification of Needs

Today the ATCOs remember a lot of information. Even though they say it works fine, an important question is, what happens the day something is forgotten? Todays equipment is limited used and do not accommodate the need of certainty. The trust in the equipement has to increase in order for the ATCOs to utilize it, and get the assistence they need. However, it is important not to provide the ATCOs with false information and create a false trust in the system. The information should therefore be honest and illustrate uncertainty.

From the users perspective, technological inaccuracy seems like the main problem with weather presentation, not necessarily graphical issues. Further, this uncertainty leads to distrust and less use of the system. The question is if a graphical presentation of a Cb will solve the problem? Both ATCOs and pilots seem not to have a problem with the existing situation. "It always works" might be grounded in the fact that they do not know of anything else. To the ATCOs, it seems to be part of the job and pride connected to keeping track of everything in their head. However, the users does not always know what they need.

"If I had asked people what they wanted, they would have said: Faster horses."
– Henry Ford

Further, the pilots commented that it "would be nice if the ATCOs saw the same as we did" when asked about change of routes due to Cbs. It was evident that this was not a big problem, but uncovered a potential for improving the amount of information provided to the ATCOs. Cbs are something you want to avoid, and more precise information can help the ATCOs handle the traffic better. As there can be turbulence in the area around Cb-activity, one would want to know the extent of the Cb. Due to the anvil-shape precipitation such as hail can come as a surprise, thus it is valuable to know about the Cb even though it is not in the current height. Further, it is important to have more information about these clouds, than what the pilot may see.

The problem is not solely avoiding Cbs. To make aviation efficient and safe one should be able to plan and optimize all routes in the air space. New problems occur when Cbs have to be evaded, and the effects of evasion disseminate in the traffic, which makes it difficult to anticipate the air traffic flow. Technical limitations was seen as the main problem but what if the technology improves, would todays graphical solution be good enough? The need of a solution functional today and in the future was uncovered. Additionally, if the technology does not improve, a solution communicating the uncertainty at the same time as it provides valuable information should be developed. Being a conservative discipline, with the challenges of change it includes, aviation would probably appreciate a solution that could follow the technological evolution. A solution that does not need to be replaced as the accuracy in weather prediction increases. As it is a comprehensive process, introducing new solutions in this discipline, sustainable solutions maintaining the important factors such as interpretation and balanced attention is valued.

Radar Screen

Switching from NATCONs dark map to a brighter version like Edda Systems' is a drastic move. The modifications done by IFE have not been tested as it is only developed for the simulator and the goal of creating a functional ATCO workstation. However, as the goal of this thesis is to develop a graphical presentation of weather it is important to know the GUI it is implemented in. Even though the GUI in both cases is possible to adjust based on personal preferences, these adjustments does not seem to be to the extent of converging the GUIs to each other graphically. Thus, developing graphical elements in general but especially for an interface different from the current solution can be challenging.

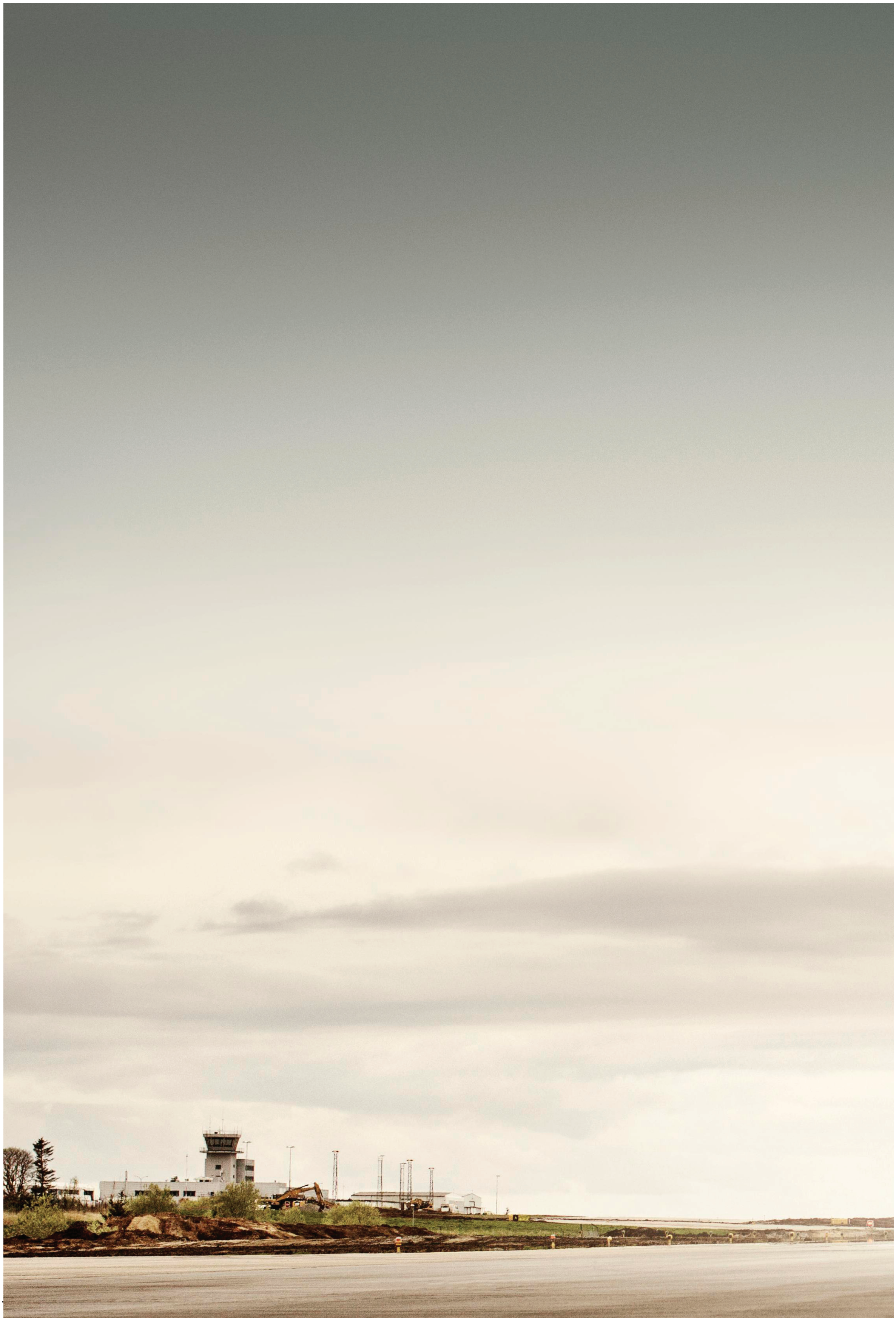
5.2 Choice of Focus

As the user-need was technology centered the choice of focus for the project was to develop a functional solution with todays and tomorrows technology. It is difficult to predict future technical improvements, therefore the main focus was to improve todays solution, and include a possible advancement. Because the project is in cooperation with Edda Systems and IFE's simulator is based on their GUI, the solution was developed for their systems to enable testing. However, it was found valuable to have NATCON's GUI included in parts of the development process, as it is the current GUI the ATCOs are familiar with. Further, the aim is a generic solution, thus both GUIs should be included in the process.

The graphic should arrange for the right amount of attention and prevent information overload. It should be easily perceived and well integrated in the GUI. Further, it should provide the necessary information and be noticeable, but not disturbing to the ATCO.

Key Findings found relevant for further development

- Cb seldom need quick response from the ATCO. It is more of an awareness, and reminder. One less thing to remember for the controller.
- Aviation is a conservative field. Small changes are probably easier to implement and get approved, than radical changes, because of documented safety and useracceptance.
- ATCOs need more accurate and honest weather information. Also regarding uncertainty.
- The layout and display on the different workstations varies.
- Edda Systems GUI is very different from NATCON's GUI. Both can be personally adjusted.
- ATCOs are handling many points of contact. They need to prevent information overload.



6 Design Brief

Introduction

The design brief converts the information from the insight and analysis part of the project, into restrictions and guidelines for further development of the concept. It identifies main challenges and goals for the development of a new concept.

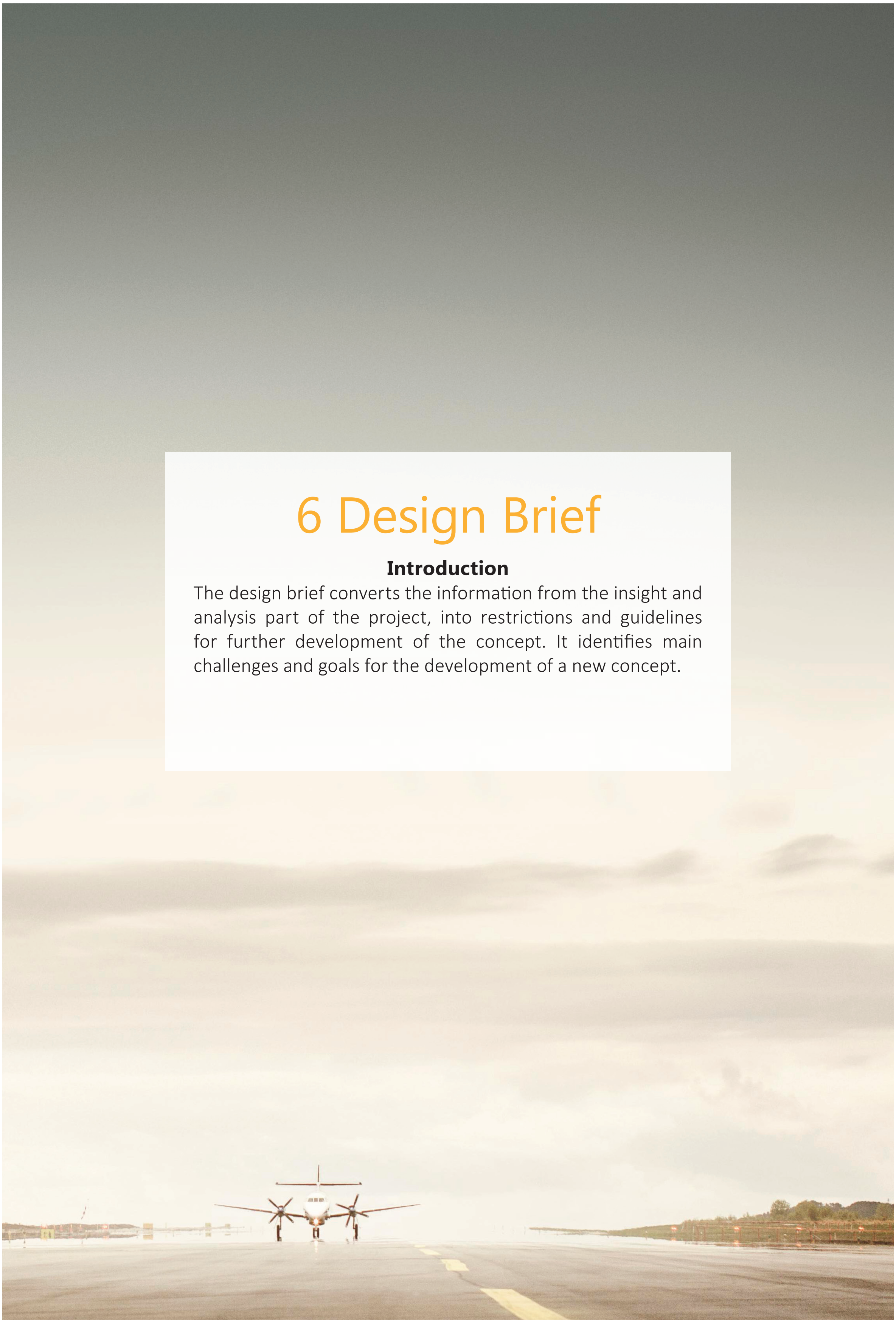


Photo: Avinor

6.1 Design Brief

In Norwegian ATC systems today there exists a graphical solution for weather information for ATCOs. However, according to ATCOs the trust in this graphic is moderate. More exact information about Cb can improve safety and efficiency in ATC. As technology is developing the chance for more accurate information increases. With a more honest and precise Cb-graphic, ATCOs trust in the information might increase. A graphic element with the capability to develop as the technology improves will be easier to work with as well as time and cost efficient. By communicating the uncertainty in the data it might become more trustworthy, and in the future more secure coordination of traffic can be done.

Delivery
The goal of this project is to develop a visualization of weather information for Edda Systems GUI that will work both today and in the future. As aviation seldom renews its systems it is important to develop a solution that will follow the evolution of technology.

- Visualization of the weather information solution
- Proposed concepts of upgrade for future technological improvement
- Master thesis
- Presentation

Main Guidelines
- Communicate uncertainty
- Arrange for acquired attention
- Develop well-integrated, but noticeable graphic
- Match the level of danger or importance
- Communicate necessary information about Cb-clouds

Main Challenges
- Maintain normal workflow, cause little change
- Maintain understanding of the situation
- Develop a visual, functional solution despite personal adjustments of the radar screen.
- Not draw too much attention.

Project Vision

The vision of the project is to create a possible solution, today and in the future, for graphical presentation of Cb-information. As it is obvious technical issues with the prediction of Cb-activity, and a trust issue from the ATCOs side, it is important to pursue an honest solution. Even though the technology is unprecise, the graphic does not need to be.

Photo: Avinor

Methods:
Sketching
Focus Group
Conspicuity test
Usability test

7 Concept Development

Introduction

This chapter summarize the process from gaining necessary theoretical insights to the development and testing of a graphical solution for Cb presentation for ATCOs. First, theory found relevant based on the guidelines in the Design Brief are presented. Then, the design process from idea to concept is described and illustrated. Two of the main tests conducted are presented. Finally, main design choices is presented, motivated and explained based on user-feedback from testing and relevant theory.

7.1 Human-Factors and Design Theory

Based on guidelines from the design brief relevant theory and literature was researched. It was found reasonable to learn more about information design and visualization. Further based on the demanding and information rich environment the ATCOs are working in it was necessary to look into situation awareness. Cb-clouds are important to be aware of, but not necessarily as an alarm, the balance of right amount of awareness and attention is important.

“How have we increased memory, thought and reasoning? By the invention of external aids: it is things that make us smart. ”

- Donald A. Norman

Perception of Information Visualization

Information visualization and effective graphics must consider human capabilities and limitations. The following section discuss this from a broad perspective; From general findings for the human vision, to how we perceive things and what can be done to affect the visual perception. At the end, key findings found relevant in connection to Cb-visualization is summarized.

The Human Vision

The human perception is limited. The human vision is best at the center of the visual field, called the fovea (Ware, 2004). From the center and out our sight gets more blurry. Our vision is based on saccades, rapid eye-movements, with a limited number of fixations per second (Porathe and Strand, 2011). We see little of the world at each moment, and are therefore in need of many instant moments. Unless we pay attention, we might not notice or remember details in our surroundings.

Tunnel Vision and change blindness

Attention can help control how the eye moves. At the same time, concentrating on one thing might cause tunnel vision, especially in stressful situations. As the concentration raises the useful field of view (UFOV) becomes smaller, and the risk of not noticing or recalling other aspects of the situation increases (Ware, 2004). Even though we see a lot of information, we might not be conscious of it all. Additionally, phenomena like change blindness (not detecting changes to an object or a scene) proves we forget things from one glimpse to the other. Thus we do not always see or perceive everything in our surroundings, even though we might think so (Simons and Levin, 1997).

Donald A. Norman states “The power of the unaided mind is highly overrated.” Further, he explains how external aids helps the human mind reach its potential, including memory, thought and reasoning. It is through finding and utilizing the right devices, to support and enhance the human mind, that it improves. “How have we increased memory, thought and reasoning? By the invention of external aids: it is things that make us smart. ” (Norman, 1993) (3:p.1) Thus, external aids can help people achieve or improve their potential of memory, thought and reasoning.

Bottom-Up & Top-Down

How we perceive something varies from where in our field of vision it is, and in what way we process the information we are exposed for. The human eye tends to look for similarities, patterns and things that are recognizable. Perception can roughly be divided into two processes: bottom-up and top-down (Ware, 2008c). In the bottom-up process a person takes in the information he or she sees, create patterns and make it into a meaningful object in their mind. Top-down is a more attention controlled process. When a goal or a task are conducted, the eye movement are more controlled and planned based on the needs to accomplish the goal. These needs affect what you interpreters out of the patterns.

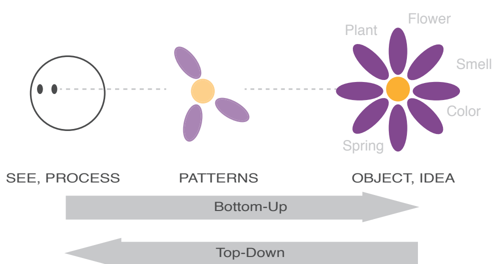


Illustration of how humans can process impressions, top-down or bottom-up. Based on illustration from Ware (2008a) p30.

Rapid Visual Perception
Visual search is the way we get new information. When the eye move rapidly around. Patterns and things that stands out from the surroundings triggers the eye movement. Further, object movement can attract attention and increase the UFOV. Getting the necessary input in a short time requires that the eye does not have to move much around. Shape, as well as color, size, orientation, motion, and spatial layout can help objects stand out, and shorten the visual search and communicate level of importance. (Lidwell et al., 2003, Ware, 2008c)

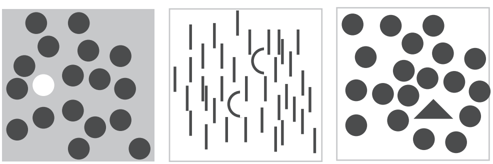


Figure showing how grey value, carvature and shape creates contrasts. The figure is based on Ware's illustration (Ware 2008b) p.30

Color Perception
Both Ware (2004) and Lidwell et al. (2003) describes how use of colors, saturation and density affects the perception of information. Use of too many colors, without a color hierarchy, may lead to tunnel vision. Moreover, it can cause important information to simply drown in the other input that the receiver is exposed to. Desaturated colors communicate professionality. Combined with dark colors it is perceived as serious, and with bright colors as friendly.

Low density can increase the useful field of view (UFOV) (Ware, 2004). The feature can be perceived as more calm, and not as an important warning. It also permits a more transparent layering of information. Non-transparent layering can lead to lack of situation awareness, because the overview of the situation is lost when the receiver has to go through many levels to get necessary information.

When working with color as a way of creating contrast it is important to remember Colin Wares statement: *Color design is subtle and can be a source of beauty and pleasure or disgust and irritation. Mostly this is a matter of socially constructed taste—there are no absolute standards.* (Ware, 2008c)

Key Findings

- External aids may help increase the human memory
- Shape and color communicates and indicates importance
- Desaturated and dark colors are perceived as professional and serious respectively
- Low density can increase useful field of view (UFOV), and can help counteract tunnel vision.
- Transparent layering helps containing SA.
- Less eye-movement can help getting necessary input in a shorter time

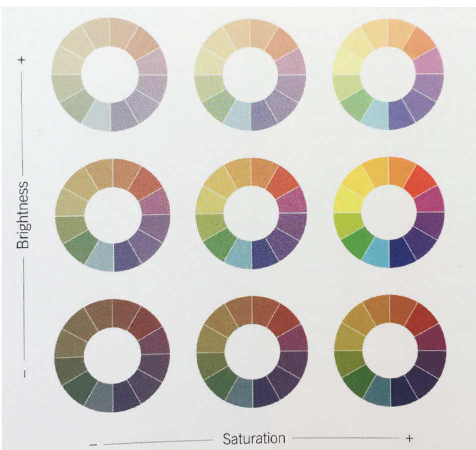


Figure illustrating brightness and saturation of colors. (Lidwell et al., 2003) p39.

Situation Awareness

In this subsection, situation awareness (SA) will be discussed, and its relevance for the design of graphical presentation of cumulonimbus. Definitions of SA will be described, as well as how it affects air traffic control and why it is important to preposition for. Finally, relevant findings for design of graphical presentation of Cb are summarized. The purpose of this section is to introduce the importance of designing for the different levels of SA, and how it can be done.

SA and ATCO
The term situation awareness is often used in complex situation where apprehension and understanding of the information around you is crucial to the accomplishment of your tasks. In situations with a lot of information it is important to be able to sort the data and see what is relevant and not. An ATCO has such a job. She has to process many different types of data, understand it, what it might mean for the traffic within her air space and coordinate planes based on the information she has got. Being able to perceive information quickly, and sort it based on importance, is a big part of an ATCOs job.

Defining SA
Situation awareness (SA) describes the understanding one gets from the environment and the information around. As Endsley and Garland (2000) puts it: "SA is knowing what is going on around you". It is created by perceiving and sorting accessible information, and by understanding what can be red out of it. Endsley and Jones (2012) divides SA into three levels. Level 1 SA: Perception of the elements in the environment. Level 2 SA: Comprehension of the current situation. Level 3 SA: Projection of future status.

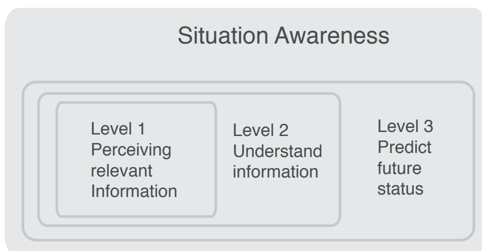


Figure illustrating the three different levels of Situation Awareness. Based on illustration from Endsley and Jones (2012)

Level 1 SA
is achieved by perceiving relevant information. Receiving the right information at the right time.

Level 2 SA
is reached when received information is understood and seen in context of possible goals or situations. Seeing the connections between the data and its possible meaning increases the value of the data.

Level 3 SA
is achieved when one, based on the perceived information, can predict near future happenings and their possible outcomes. It enables people to be proactive and make qualified decisions e.g. help ATCOs anticipate complicated situations or problems in advance. Level 3 SA requires strong mental resources and domain expertise. Thus, maintaining this SA level can be mentally demanding. Information overload can make it harder to form and maintain the highest level of SA, it is therefore important to assure and obtain level 1 and 2 SA.

SA in Design
All above describes what situation awareness is to the user. In the context of design, these requirements can be seen as, Level 1: the design contains the necessary data. Level 2: The data is presented in an understandable way, in coherence with the existing situation. Level 3: The presentation of the data communicates near future situations or happenings. Endsley and Jones (2012) empathize well-designed information systems and user interfaces as an important factor to develop and maintain level 1 and 2, and further assure level 3 SA.

Designing for SA means ensuring that the necessary information is obtained by the system and presented in a way that makes it easily processed by the system users who can have any competing pieces of information contending of their attention.

Endsley and Jones (2012) p. 16

SA in aviation

When designing to support ATCOs building a high degree of SA one must look into their work situation, as SA differs between professions (SKYbrary, 2016). The information required for the ATCO to achieve SA would involve planes in their air space, flight plans and possible future situations based on e.g. weather forecasts (SKYbrary, 2016).

It can be particular difficult to obtain the first two levels in air traffic control (Jones and Endsley, 1996). As en-route ATCOs often are located far from the situation e.g. Røyken ACC, without any windows there are less contributions to the SA. The ATCOs are more dependent on information from their equipment, as well as direct radio-contact with pilots and other ATC sectors. Pilots can be the ATCOs eyes in the skies. However, there is uncertainty in the data collected from MET Norway and pilots. Jones and Endsley (1996) found that 76,3% of ATCO's and flight crew's SA errors were level 1; not receiving or perceiving information correctly. Thus, the information from the flight crew might not always be correct. This can affect the ATCOs SA-level1 in a negative way, not receiving the necessary data. Further, Jones and Endsley (1996) (p. 17) claims that Approximately 19% of SA errors in aviation involve problems with level 2 SA. Following, people do not understand the information in the context of the situation they are in. They might get the necessary information needed in a situation, but does not manage to understand the meaning of it.

Experience creates the needed mental model

As Jones Endsley (2012) describes, young pilots might have more difficulties understanding the total situation and achieve level 2 SA compared to older, more experienced pilots. The same can probably be said about ATCOs, as level 2 SA requires experience or a good mental model to transfer received information into valuable insight and understanding. Hence, newly educated ATCOs without experience are less qualified to achieve level 2 SA like other ATCOs.

MENTAL MODEL

A mental model is how you picture e.g. a situation or an organization in your mind including all the stakeholders and connections that is relevant. Endsley and Jones (2012) defines it as a systematic understanding of how something works.

Designing for SA in the case of Cb-clouds

To support ATCOs building a high degree of SA when Cb-clouds occurs all levels should be achieved. As the ATCO rarely see the Cb-clouds directly, they have to rely on the information provided by the MET Norway and pilots. Their understanding of the situation is therefore limited. To support SA level 2, this data must be comprehended for rapid visual perception. The graphical challenge here is to find suitable visual shapes representing Cb-clouds without creating disturbances. As the information provided to them in some cases can be incorrect, it is an important part of their SA to be informed about this uncertainty. When arranging for SA it is not only need of correct information. Notifying of possible uncertainty or lack of information is as important, to improve the overall understanding of the situation. To enable the ATCO to predict future happenings in level 3 SA, it is essential that they can take into account the possible uncertainty of the information. Additionally, it is important that the confirmation of the uncertainty does not demand extra work or energy for the ATCO. Thus, it should rather be integrated in the visualization of the information. A look should be enough to determine that there is a Cb-cloud in the area, approximate size and communicate that the information is approximate. Based on the previous discussion on the three SA levels it is reasonable to design graphics that communicate the necessary data in a short time, but at the same time show possible uncertainties in the data. Further, to support level-3 SA, an indication of the future status of the Cb-clouds must be visualized. This is particularly challenging given the uncertainty of the weather data.

Key Findings

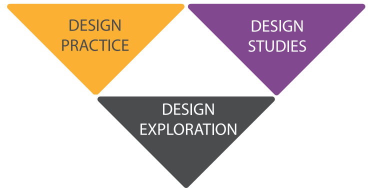
- In order to not take unnecessary focus the Cb-graphic need easily processed information in coherence with the situation.
- Avoid information overload by only providing the necessary information.
- Quickly and easy distinguishable Cb-graphic from other graphical elements and the background.
- Cb-graphic should be designed to fit the graphical hierarchy in accordance to its level of importance.
- Given that the quality of the information provided might vary it is important that the ATCO is aware of possible uncertainty in their data. Introducing this uncertainty through the graphic and in direct contact with the data eliminates the need of looking other places for confirmation.
- Needs a good mental model.
- Time perspective is important to establish SA level 3.

Discussion , Human-factors and Design Theory

As Don Norman states, external aids can help improve the power of the mind. In the world of ATC there are a lot of “we just remember it”. Adding external aids might improve the capacity of e.g. memory. Introducing a new element to the ATCOs equipment it is important not to challenge the current safety measures. In order to establish and maintain SA it is crucial to avoid information overload and tunnel vision. It is important for ATCOs to be able to sort the provided information. Color and shape can help place the Cb-graphic in the hierarchy of information, and quicken apprehension and decrease necessary eye-movement.

The balance of level of importance is crucial. The Cb are often something the ATCOs already know about. Thus, the visualization of the information should be a help to remember and keep them aware over a longer period (Cbs lasts for approximately one hour), not be an active warning.

Time perspective is important to establish SA level 3. However, with today’s technology it can be difficult to predict the Cbs movement and duration. As the information already provided, such as placement and extent, includes an uncertainty adding more insecurity to this data might work against its purpose. The balance of accuracy is difficult as the ATCOs will most likely choose not to display the graphic if it does not provide enough relevant information, or if it the information provided is too uncertain. Further, it can be argued that, as most SA errors are level 1, followed by level 2, developing for SA level 1 and 2 will cover a greater part of possible SA errors.



7.2 From Idea to Concept

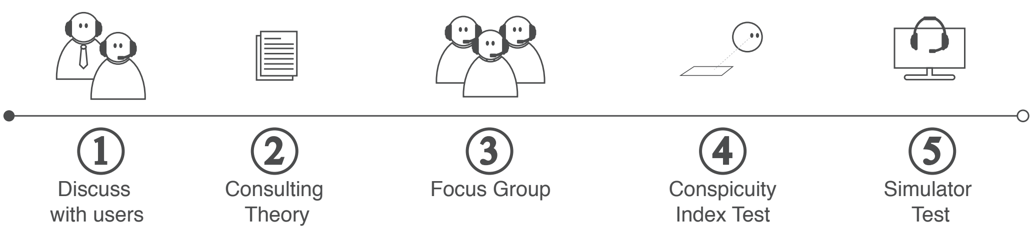
In this section the concept development is presented. The process is described from idea generation up to the final concept. Ideas was generated from the beginning of the project, in parallel with the insight and analyzing process. After the focus area was specified the ideas was developed further in accordance with the design brief. Through iterations with testing and analyzing, the ideas was combined with insights and theory gathered. An overview of ideas can be found in appendix.

The Process

The development process started by taking a step back and challenging the task given by IFE and the solution oriented ATCOs: Did it have to be a graphical element? In the first stage the ideas were more radical. Then, sketching of patterns, colors and shapes began to find the optimal design of conveying needed information, first on paper and later digital sketches. Keeping the sketches low key lower the threshold for the user to say what they mean. Further, a sample of shapes was placed in context (on map) in order to see and test the visibility and harmony, in focus group and through a conspicuity test. In the end, one solution was implemented in a functional simulator where graphical interpretation and the animation of appearance where tested. Regularly feedback from users combined with theory throughout the project created and iterative process with five main iterations. By trying and failing often, the project kept developing and improving.

Iterations

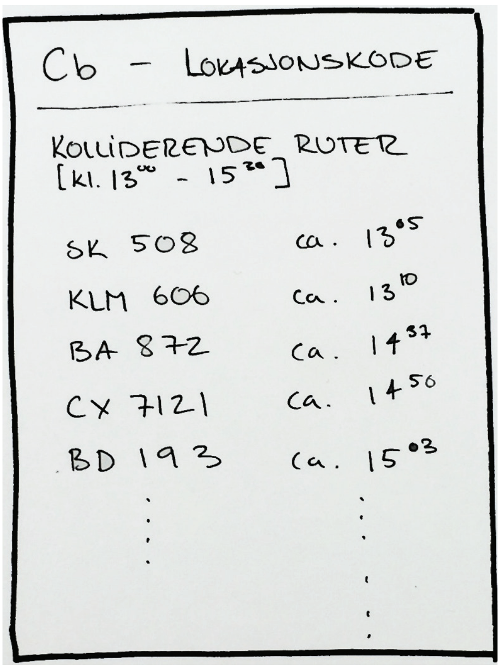
The developing process had five main iterations, in addition to several smaller iterations throughout the process. The sketches are presented along with how the iterations happened, and what they resulted in. These iterations led to the design choices, which are described further in chapter 7.4. More sketches from the development process can be found in appendix.



Timeline illustrating the iterative development process. Showing the main iterations.

Iteration 1:
Paper sketches, Realistic - non realistic

Starting, I wanted to have a broad approach to the problem. Many ideas was sketched, both on the radar screen and for other location on the ATCOs workstation. To quickly sort the ideas between “not realistic” and “has potential” they were presented to ATCOs, and discussed informal.



Sketch of a non-graphical solution. After discussions with ATCOs, and based on theory it was found less efficient than a graphical element on the radar screen.

Findings

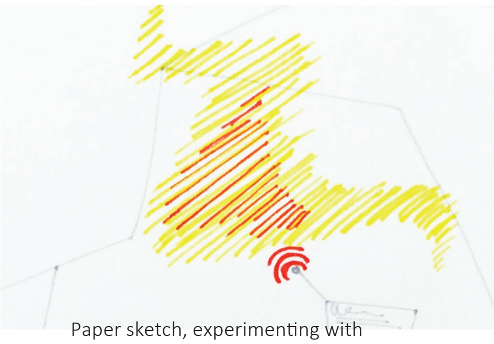
- A graphical-element on the radar screen demands less eye-movement (And the ATCOs have TAF and METAR on other screens, thus if they have to look around they can just as well look at RANDIS, the weather screen).
- Do not need many layers on intensity. Pilots probably want to go around anyway.
- The solution should be honest, in the way of communicating uncertainty in the data provided.
- Too much color is disturbing as it do not match the map.
- Data presented in number is perceived as accurate numbers. Do not like to get something presented as a truth if it is not.

Iteration 2:
Paper/Digitale Sketches: Theoretical analysis

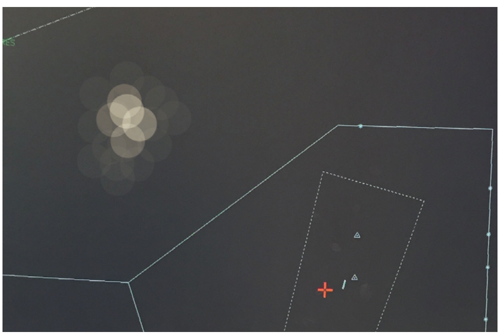
Paper sketching continued, and some sketching in Adobe InDesign and Illustrator started. Theoretical analysis was conducted, focusing on situation awareness, information visualization e.g. density, color, transparency, and information regarding Cb-activity.

Findings

- Circles is a contrast to the sharp edges of the map
- Color demands attention
- Alarming colors might be too serious. Cb are seldom alarming, as they are most often predicted.



Paper sketch, experimenting with colors and lines.



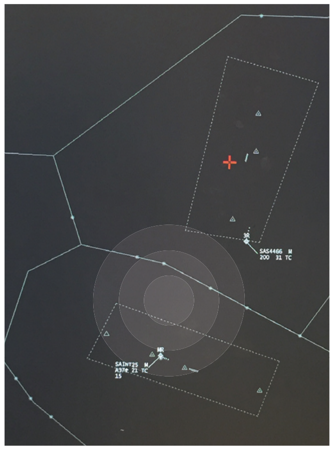
Digital sketch on NATCON's map.

Experimenting with dots, lines and colors.

Iteration 3:
Digital Sketches, Focus Group

Based on iteration 1 and 2 a sample of the sketches was chosen to develop further, and sketched digitally in Adobe InDesign and Illustrator. As the concept is developed for Edda Systems system with a different map background, both the current and Edda System's background was used in the process of developing and testing solutions. As introducing a new element on a new background would most likely affect the feedback one get. Further, the developing process focused on Edda Systems map.

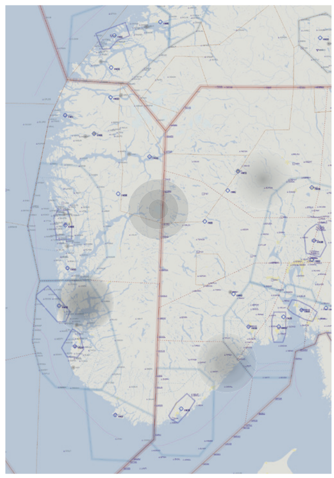
The digital sketches was discussed and evaluated in a focus group with ATCOs. Sketch 7, version 2 and sketch 4 was brought up as favorites, and discussed the most.



First the ATCOs was introduced to the sketches on the current, NATCON, map.

Findings

- Focus on clean, simple shapes ex. Circle
- Does not like marked, definite lines and borders "it is scary to send a plane over a border!"
- Bright colors can be interpreted as danger.
- Think the circle can be misleading, as a Cb is not circular.
- The fact that the graphic is circular communicates that it cannot be trusted 100%
- Too diffuse or "cloudy" shapes disappear in other graphic.
- 2 Levels of intensity is fine. 3 is too much.
- Gradients in the existing system, NATCON, is difficult.



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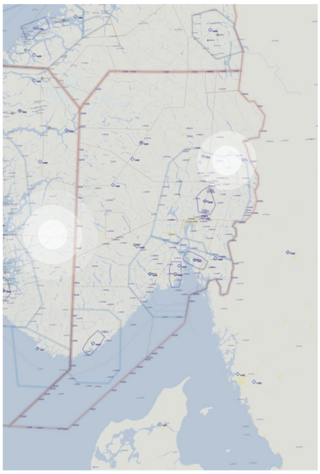
Sketch 7: (Introuced after positive feedback on sketch 2) Liked version 2, even though a Cb is not circular. Diffuse boarders

The sketches presented to the focus group:
(The order of the sketches presented here, is not the order they where presented to the focus group.)



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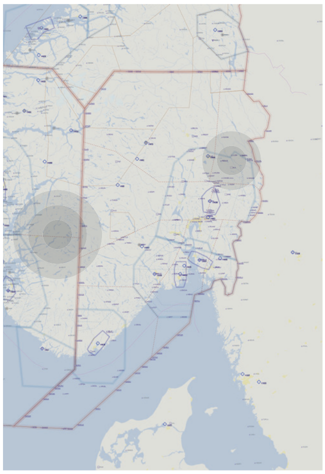
Sketch 1: “This is too bright. We do not want white on the NATCON map as it is perceived as danger.”



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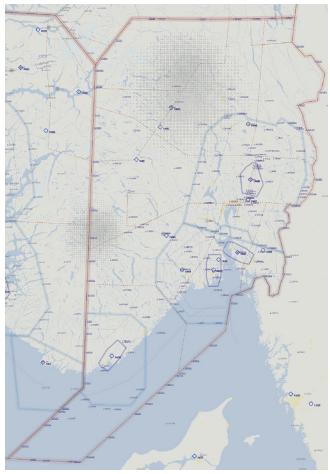
Sketch 2: Like. But only two circles are needed. Do not like the definite boarders.



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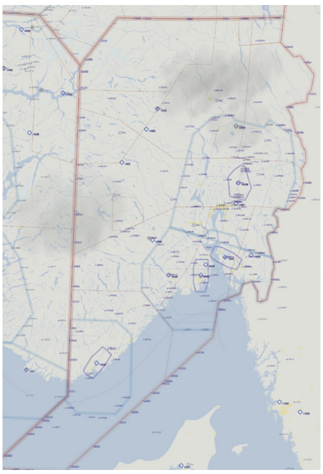
Sketch 3: Not visible enough. The ATCOs found it hard to understand what it covered of Cb-activity.



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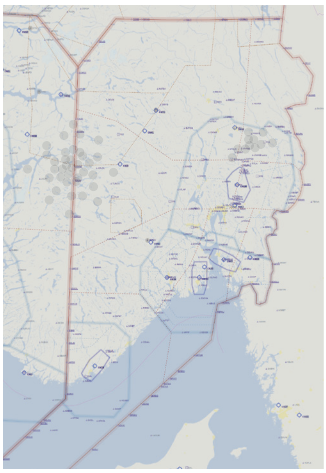
Sketch 4: “This is ok, it reminds me of the existing solution.”



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Sketch 5: Not discussed based on feedback on sketch 6. Too noisy. (too many dots).

6

Sketch 6: Low visibility. “I do not understand the dots in the pattern. Are all of them Cb-clouds? That is a lot of dots.”

Iteration 4:
Digital Sketches II, Conspicuity test

Based on feedback from the focus group, previous insight and theory, a new iteration led to four sketches, including the "favorites" found in the focus group. To test the visibility and see if what the focus group said was correct. The sample covered clean shapes, asymmetric and cloud-like shapes and both hard and diffuse lines. See Chapter 7.3 for more details.

- The symmetric, circular shapes scored best on conspicuity.

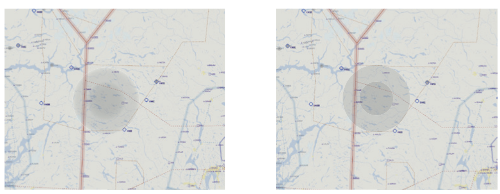
After four iterations, including the conspicuity test, the finalizing of the solution began. The findings from earlier in the process was combined with the result from the conspicuity test and a concept for final testing was developed. The circular, symmetric alternatives scored highest in the conspicuity test. Its shape was through theory analyzed to have a good contrast to the map in the background. It was calm and did not create unnecessary noise. The users had until now seen it as an ok solution, with some modifications. The outlines were made more diffuse, and the two levels of intensity kept.

Iteration 5:
Digital Sketches III, Formative Usability Test

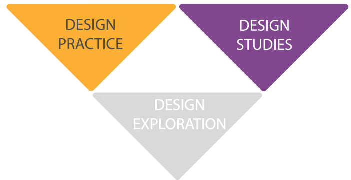
A scenario test in IFEs ATC-simulator in Halden led to the last iteration. Up until now the animation of the graphic had not been tested. Further, overall usability was tested. The purpose of the test was to discover serious design flaws. Additionally, feedback from the user on the overall impression of the solution was gathered through a evaluation-scheme.

After the last simulator test few changes were made, as the overall design got mainly positive feedback. Additionally, possible concepts to indicate the direction of the Cb was developed based on the participants feedback, to accommodate future technological improvements. This had not been a focus during the process due to technological limitation, thus they were added as possible upgrades of the tested solution.

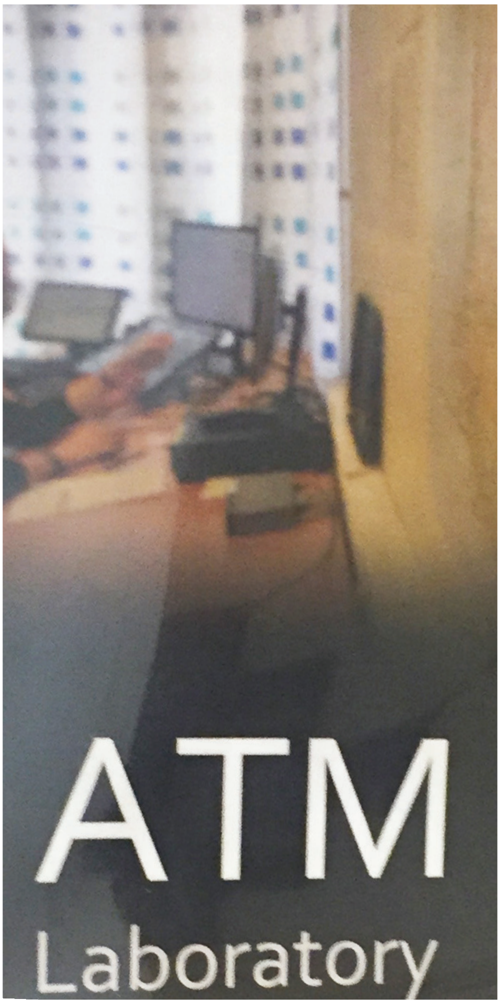
Both tests in iteration 4 and 5 are more thoroughly explained in chapter 7.3.



Conspicuity Index Test: The two sketches with highest Conspicuity Index.



7.3 Testing



Sign on the door into the ATC simulator at IFE, Halden.

During the development process two more comprehensive tests were conducted. First, the conspicuity index was tested in order to discover how visible and distinguished different graphic were. Additionally, it was interesting to test some of the focus group's assumptions. Finally, an overall usability test was conducted in IFE's ATC simulator in Halden. Two different scenarios was staged in order to test perception, understanding and some level of utility. The results from the usability test led to the final concept

Conspicuity test

Purpose with the test

Visibility is an important factor for the solution. However, the balance between visibility and noise on the radar screen is important. Thus, the information should be easy to see, even when the focus is on something else. I wanted to see if there were a difference in visibility in the 4 sketches, and which scored the best. Testing two almost similar objects (sketch 1 and 3) could show how big effect diffuse lines could have on the visibility. Thus, hopefully uncover decisive factors, and validate what the focus group stated. In order to test the visibility of the solutions a Conspicuity test was conducted. Simply put; The chance of spotting the target within the conspicuity area increases as the conspicuity index increases. A more comprehensive description of what a conspicuity test is can be found in chapter 3.2.

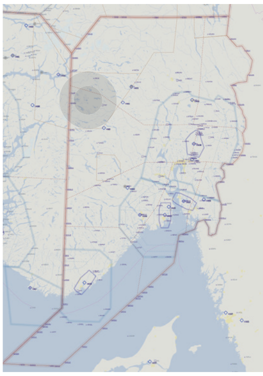
Method

- Large sheets of paper
- A stick (to keep the head at specified distance from paper), 57 cm
- A pen
- Ruler
- Printed versions of the solutions to be tested, on map-background.
- Computer, for note taking and results

Participants:
Five students in the age of 22-26 years old where tested. All had normal or corrected to normal vision.

The participants where to rest their head at a 57 cm long stick, placed slightly above the printed sketch. Starting by pointing the pen at the visualization of the Cb, then slowly moving the pen and eyes to the side. They where asked to set a mark on the paper at the side when they could not detect the visualization in the periphery. The same procedure was done three times to each side, on every sketch. The order of the sketches varied between test persons to avoid learning effect.

The test was conducted on paper to save time, and make the test low-key even though the solution will be screen based. As the test is based on comparison between different alternatives, and all alternatives was presented using the same equipment and method, it was found likely to believe that the paper test result would be representative for the project. Mainly giving an indication for further testing.



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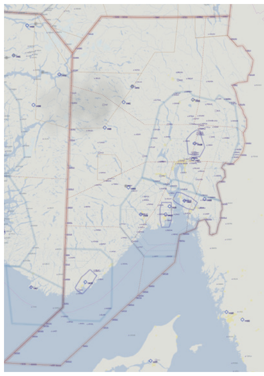

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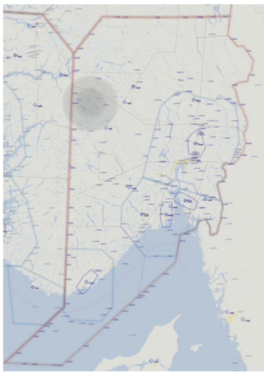

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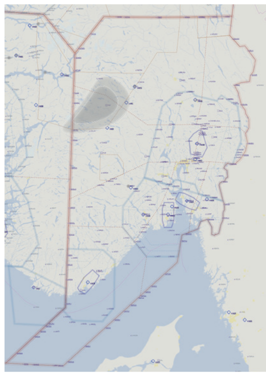


4

The sketches tested in the conspicuity index test.

Results

Sketch 1 and 3 score highest on the conspicuity index. 2 have the highest variation in the results, with highest standard deviation and confidence level.

Sketch	Mean[cm]	SD[cm]	N	95% confidence level (cm)	Conspicuity index (deg)	95% Confidence level(deg)
1	42,68	9,06	5	7,94	36,83	6,85
2	36,23	11,13	5	9,76	32,44	8,74
3	41,73	9,19	5	8,06	36,21	6,99
4	38,15	8,33	5	7,31	33,79	6,47

Calculation of conspicuity index (deg):
tan ¤ = Mean[cm]/57[cm]

Table showing the calculations and results from the conspicuity index test.

Discussion

No great differences was uncovered due to the test. However, it is a gap in the result between 1 and 3 with conspicuity level around 36,5 degrees, and 2 and 4 scoring around 33 degrees. It makes sense that 1 and 3 scored quite equal, as they have graphical similarities. Even though 3 have diffuse boarders it did not impact the conspicuity level much. As seen in the table on page 103 the difference is 0,62 degrees as conspicuity index of 1 is 36,83 degrees and 3 is 36,21.

It is important to keep in mind that only five people were tested. Even though it is, as mentioned previously, evaluated as enough participants in some cases (Porathe and Strand, 2011, Nielsen, 2011), it is a possible source of error. The participants conducted the test three times, both left and right, on each sketch which helps assure quality of the results. However, to save time and paper the sheets was not switched out between each test thus the participants could see her own marks on the paper. This can have had an effect on the results, even though the participants was asked not to take notice of their previous marks. It was not seen as an essential factor, compared to that it made it easier and more efficient to test more people. Further, it should be clarified that the participants did not affect each other marks, as the paper was switched between participants.

Participant during the conspicuity test

Findings

Even though the variation in the result was limited, the gap in the result can indicate which features that affect the conspicuity. As 2 and 4 scored the lowest, and both have the most asymmetric shapes it can look like it blends more with the surroundings. Further, the difference between 1 and 3 was small, as the only inequality was the diffuse edges of the circles in 3. Thus, softening the edges have not affected the visibility significantly.

- The asymmetric shapes blends more in their surroundings
- Diffuse boarders does not significantly affect the visibility of the object

Formative Usability Test: Simulator Test

A simulator test was conducted to test the usability of the graphic, mainly focusing on interpretation. It was attempted examine the utility of the solution, but as it is dependent on technological improvement on prediction of weather information, this was hypothetically based. The test results was positive to the graphical presentation of the Cb. The graphic being clean, easy to understand and communicating possible uncertainty was emphasized. Documentation from the simulator test can be found in appendix.

Purpose with the test

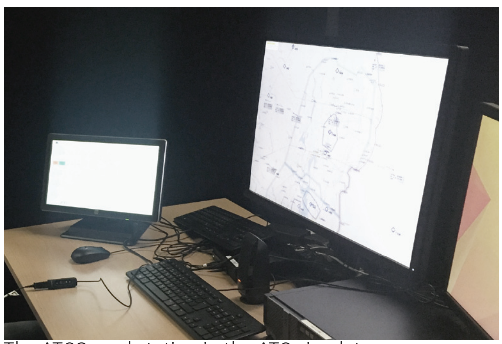
The purpose with the test was to see the overall usability of the solution in a near to realistic environment and uncover overall design shortcomings. The test should give an indication on how well the graphic is understood, how fitting the animation of the emerging Cb is and the utility of the solution.

Method

- IFE's simulator, based on Edda Systems system
- 4 Participants: Operative ATCOs
- 2 Pseudo pilots: Employees at IFE, former ATCO and/or pilot
- iPhone 6 for filming and documentation

The participants:
D1: 25 years old. Female. 3 months as an ATCO
D2: 43 years old. Male. Over 10 years as an ATCO
D3: 25 years old. Male. 1 week as an ATCO
D4: 58 years old. Male. 37 years as an ATCO

The formative usability test was conducted in IFEs ATCsimulator, consisting of the necessary screens, radio contact and other equipment to stage an ATCO's workplace. The simulated planes was controlled from another room, also creating "real" radio contact. Test participants were asked to conduct their tasks as normal, while being observed and occasionally asked questions. The whole session was filmed. It endured for 30 minutes divided into two scenarios of 10 min, 10 min of additional questions and filling out a evaluation-scheme.



The ATCO workstation in the ATC-simulator.

Preparations
The simulator test of the Cb-graphic was part of a bigger test conducted by IFE. Thus, coordination with IFE while preparing the test for the simulator was important. Discussion on the form of the test, planning the air traffic of the scenarios, and implementing the test in the simulator all needed different people. Thus, coordination was required to keep the deadline.

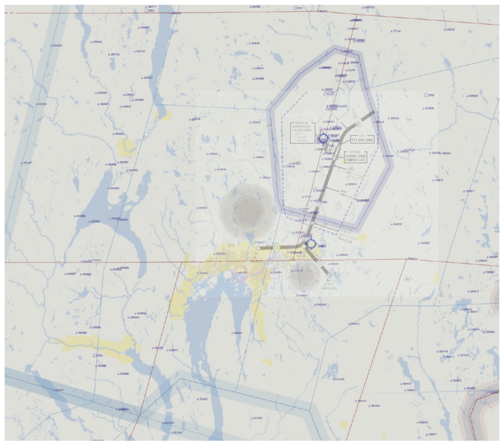
The participants was ATCOs recruited through Avinor. They where contacted in advance and informed about the test and the team around it (see information flyer in Appendix). However, it was only informed that the last part of the test would include weather information, not specifying what kind of weather.

The Scenarios
Two different scenarios was introduced with different air traffic to prevent the participants from learning the pattern. The workload of the scenarios varied but was mainly moderate so the ATCO was able to answer questions while working. The scenarios was static, without any movement of the clouds. This is not realistic, but due to technical limitations and the duration of each scenario. It was evaluated to be of no significant influence as the graphic was the most important aspect in this test, and movement was not significant part of the solution. The scenarios are further described in appendix.

The pseudo pilot part of the simulator.

Scenario 1

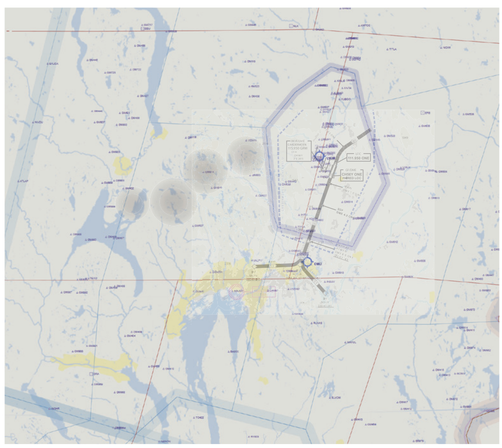
Scenario 1 contained two Cb-cells, emerging with some time difference. They had strategic placements near the approach to the airport.



Scenario 1

Scenario 2

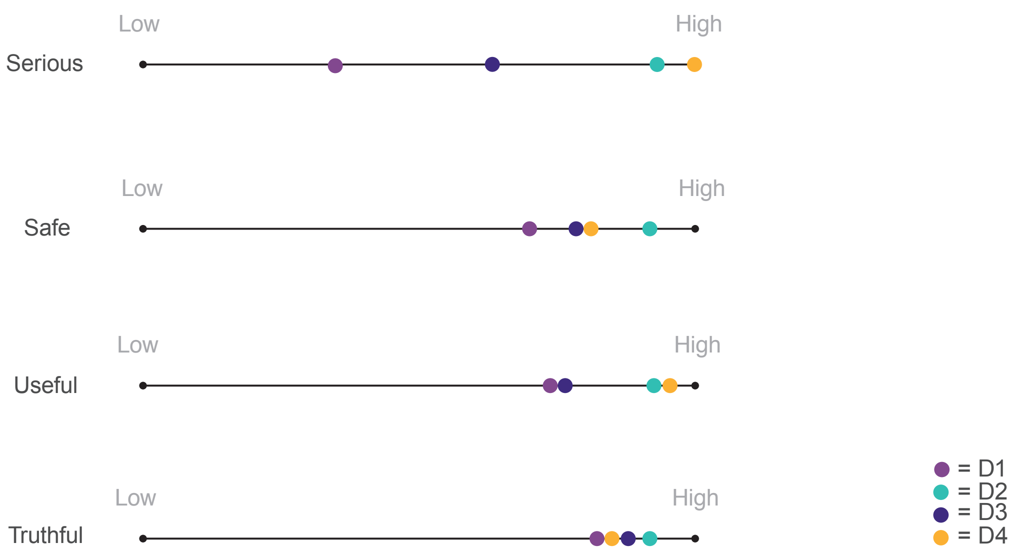
Scenario 2 contained of a row of Cb-cells, creating a wall which are one of the more challenging ways Cbs can occur. There where opened a small passage between some of the cells to see if the ATCOs take the chance of sending planes through this opening.



Scenario 2

Evaluating the graphic

Finally, the participants filled out a scheme displaying four bars one for each factor: Serious, Safe, Useful and Truthful. On the bars the participants could set their mark freely on how they perceived the graphic, with the anticipation that the technology for estimating and predicting weather would improve in the future. How great the technology improvement would be was not specified. The numbers was excluded from the bars to avoid guiding or affecting the test participants too much. Not forcing them to choose between levels, gives them more space and levels to communicate the score.



Evaluation scheme. Feeback from the participants in the simulator test

Results

- All perceived it as bad weather, with varied intensity.
- The coloring was perceived as intuitive, as bad weather often are dark.
- The graphic was visible enough, not taking too much attention.
- 2 levels of the graphic is enough. No need for more or less.
- Perceived as informative, but with an uncertainty

If the technology is correct, it is useful. Would have been nice with time estimation of movement, direction or altitude, as long as it is correct and does not disturb more important information. The participants see it as difficult to achieve. “It can be a little too much information”.

“This one is better!”

– Participant D4, comparing the test solution with the existing solution .

Discussion
Over all the participant was positive to the proposed solution. They all perceived it as bad weather, three of four participants even understood that it was Cb-activity without any guidance. As ATCOs are trained for several years before they start working, they will have time to learn the graphic. However, in a stressed situation it can be helpful that it is intuitive.

Further, they all liked the color as long as the solution was to be applied in the same map as the simulator. No one jumped as the Cb-cells emerged, but maintained calm. Few of them did not seem very interested in the graphic after establishing what it was, rather focusing on their job. This was interesting to see, and understood as a positive reaction as it is not supposed to create much engagement, rather be informative and a bit in the background. It seemed like they had no problem adapting the new graphic in their work, some taking it more into account than others.

It was not before they where asked to say something that could improve the graphic that time estimation of movement, altitude or direction was mentioned. All added that it would be difficult to predict. Adding some of these features would increase the situation awareness level 3. However, it is difficult to predict with todays technology. Also as the participants mentioned, it must be done in a way that avoid too much information on the radar-screen. Supplements from METAR and TAF can therefore be valuable here, at least on altitude. Further, in real life, movement will be seen on the screen. Not be static as the test scenarios.

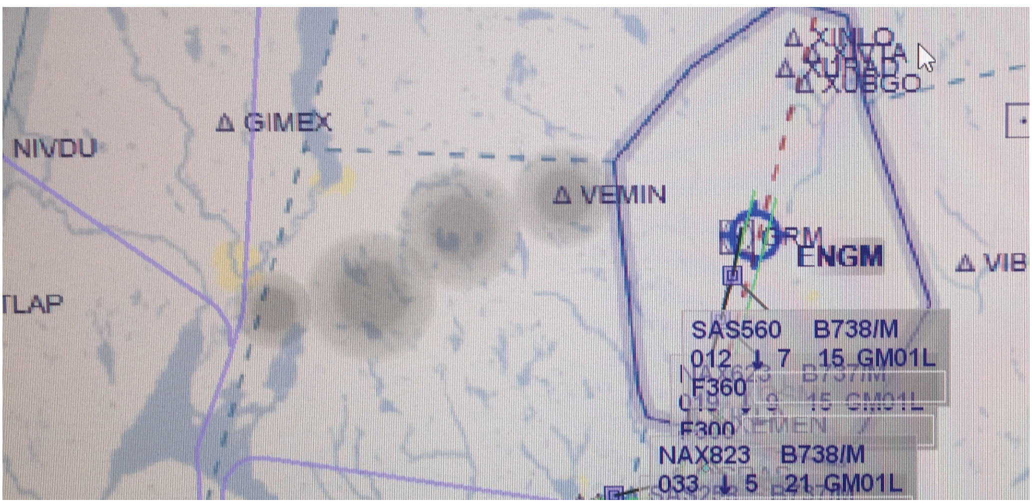
As the test was exploratory, not introducing or explaining the solution to the test persons before conducting the test, the test shows the participant's reaction and interpretation of the graphic. It is possible to see how she choose to use it in an investigating manner. Thus, it does not show how the participant would use it as a tool in her work, after getting to know and train with it. As I am not an expert observer, trained in air traffic control, it would be difficult for me to determine how efficient a participant conducts the tasks with or without the graphical cloud information. Further work and testing of the solution should include expert observers who can help uncover the effect such a tool has.

There were some minor disturbances due to unfinished graphic simulator. Such as the labels for other airports that were in the same grey color as parts of the Cb-cloud. Thus, it was not easy to distinguish them from each other. As this was spesific for this simulator and not Edda Systems' system, it will most likely not be a problem in the "real world".

Being a qualitative based test and with only four participants could only give an indication of possible significant design mistakes. However, in qualitative usability tests it is discussed whether or not there is a need of many participants. Nielsen (2012) argues that five often is enough to uncover big design mistakes or problems in qualitative tests.

Findings

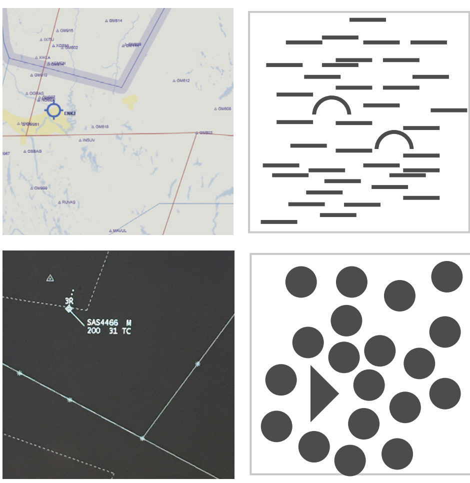
The solution was perceived as intuitive and fitting to Edda Systems simulator. It was visible without creating noise on the screen. The animation was discrete, not taking too much attention. Based on the feedback from the particiants. Including altitude, direction or time estimation of movement would improve the utility, as long as it is done in a non-disturbing way.



Scenario 2 implemented in the simulator. (Picture of simulator screen)

7.4 Design Choices

In this thesis the focus have been on developing a graphic communicating available and needed information. The contrasts of shapes have been used to distinguish the graphic, and the color used with the aim to communicate importance, as well as keeping the graphic discreet. This subsection describes the main design choices. Decisions made along the way follows, supported by theory, focus group, conspicuity- and usability tests. The motivation of the design and animation is explained and should give the reader an understanding of why these choices were made.



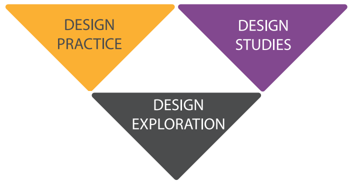
The GUI in Edda Systems (upper left) and in NATCON, (down left) have sharp edges and stright lines. As shown in the figure from the chapter 7.1, shape and curvature can create contrast.

Circular shape

The shape of the graphic was set to be a circle. It was found trustworthy and honest, as it communicates the uncertainty of the data. The ATCOs know well that a Cb is not shaped like a perfect circle. The graphic encourage using the shape as an indication more than a fact. The perfect form of a circle is easily distinguished from the sharp edges of the map. The dynamic shape creates a clear contrast, without being a big eye-catcher. As the screens colors, saturation etc. can be personal adjusted differencing the object from the surroundings by the shape maintains the contrast. Thus, the object is not as dependent on the color contrast to be visible. Further, both GUIs (Edda Systems and NATCONs) have the sharp edges in common. Thus, the contrast is valid on both maps.

Based on the limitations in the software, both in the one the ATCOs uses today and IFE's simulator, simple geometric shapes is easier and more realistic to implement.

The shape was kept simple, showing in all altitudes and not in e.g. 3D. As it can be valuable to know about Cb-activity in many different altitudes due to possible surprising precipitation from the top of the cloud. In the future, this is something that can be adjusted when more accurate information is possible.



Color, Opacity and Contrast

During the developing process different colors was experimented with, but the result ended up with a grey, transparent design. As desaturated and dark colors are perceived as professional and serious, it was found fitting to communicate information about Cb. Additionally, grey does not create an unnecessary contrast to the rest of the bright grey-based GUI in Edda Systems software (or in NATCONs dark grey GUI). Low density can increase UFOV, and help counteract tunnel vision. The transparent layering helps containing SA, not blocking out other relevant information e.g. boarders underneath the object. Further, the object can be small in relation to the map on the radar screen, thus the grey tone should be in a visible contrast to the color of the background.

Web Content Accessibility Guidelines 2.0's (WCAG 2.0) demands to color contrasts was taken into consideration during the development process. Further, the color contrast tool Color Contrast Checker was utilized to control the contrast (See http://webaim.org/resources/contrastchecker/). However, this graphic was developed for a specialized group, trained to stare at the screen more intense than normal screen-users. Thus, the demand for contrast and visibility is lowered and the need of universal design, making it accessible for everyone, not as necessary. Even though color contrast is important to maintain visibility, it was in this case evaluated as less consequential, as ATCOs have different needs.

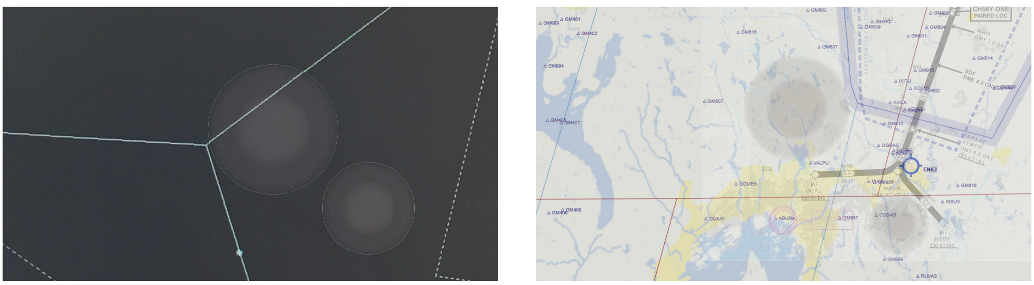


Illustration of the color, opacity and contrast in NATCON (left) and Edda System (right). In NATCON the color of the Cb-graphic is inverted, from black to white base color, to create the contrast, as the two maps have different base colors.

Two Intensity Levels

The graphic consists of two circles. The idea behind the outer circle is 1) to visualize milder weather and 2) To visualize an uncertainty of extent of the weather 3) open for tolerance in the accuracy of the future technology. The inner circle illustrates the area with the most activity e.g. precipitation. Having to levels opens up for the technology improvement as it can be adjusted accordingly. Based on feedback from the focus group two levels of intensity were appropriate, as they seldom need more information to navigate planes around. More than two layers would be hard to predict and demand more work load for the ATCOs to decide which level a plane can fly through.

Marked vs Diffuse lines

The ATCOs does not like when something is presented as a truth or facts when it is not. Harsh lines and definite borders were read as facts, as if the shape covered all bad weather and on the other side of the line there where no Cb-activity. Additionally, they did not like the idea of having to navigate a plane over a definite boarder, even if that was what the pilot wanted. By softening the outer lines of the circle it communicates that it is approximate information. Thus, to be on the safe side even though all relevant weather should be at least covered by the outer circle.

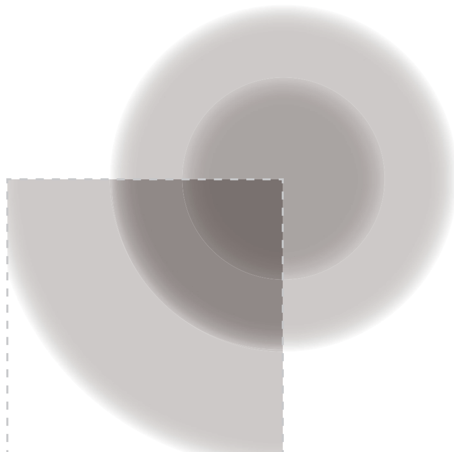


Illustration showing the two layers. The cutout gives an impression of how it would look with more levels, and shows the diffuse outlining.

Animation

As mentioned in chapter 7.1, movement can attract attention. Thus, the emerging of the Cb has to be adapted to the level of importance, not drawing too much attention. Based on theory of situation awareness and information evaluation it was natural to keep the emerging animation calm. A gradual animation of 5 seconds was found to be most suitable. An abrupt graphic emerge would be disturbing and draw attention. Too slow animation would not be efficient and might not be noticed in a long time.

As the Cb-activity ends the graphic is gradually animated away. Again, no abrupt movement is created in order to not draw attention to it. Sudden disappearance can cause the ATCO to notice something moving in the periphery of her eye, but as it disappears she does not know what it was. Possibly, it can create unnecessary feelings of insecurity. The ATCO should have enough time to reflect on what is happening. Thus, the animation should gradually fade away.

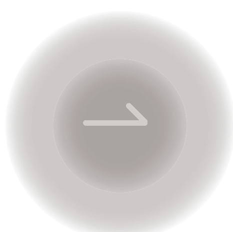
As the graphic was the focus in this project, the animation was not prioritized in the development phase. Only one concept was tested in the formative usability test. However, the five second gradually emerging animation of the Cb got no negative feedback from the participants in the simulator test. Thus, the animation seem suitable for its purpose, not taking too much attention when emerging. This should be tested further, to quality assure the assumption.

Future direction indicator

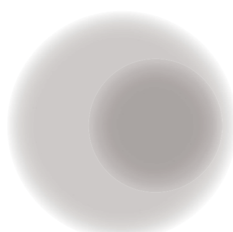
Based on the feedback from the simulator test and theory on situation awareness, concepts for illustrating direction was developed. To create SA level 3 a direction indicator was added to the graphical design. This is, as mentioned in the earlier subsection, not prioritized nor tested. However, it was discussed with users during the process and in the last formative usability test. Two concepts for possible presentation of direction of movement were developed. As they have not been tested, the purpose of the concepts is to show different ways to integrate means to gain SA level 3 in the proposed graphic solution. Further, more testing is proposed.

Concept 1: A transparent arrow in the inner circle show the predicted direction of the Cb. This is an intuitive symbol that does not take too much attention, with the right color, that is. The downside is that it might be difficult to communicate a possible uncertainty. As an arrow can be seen as a fact.

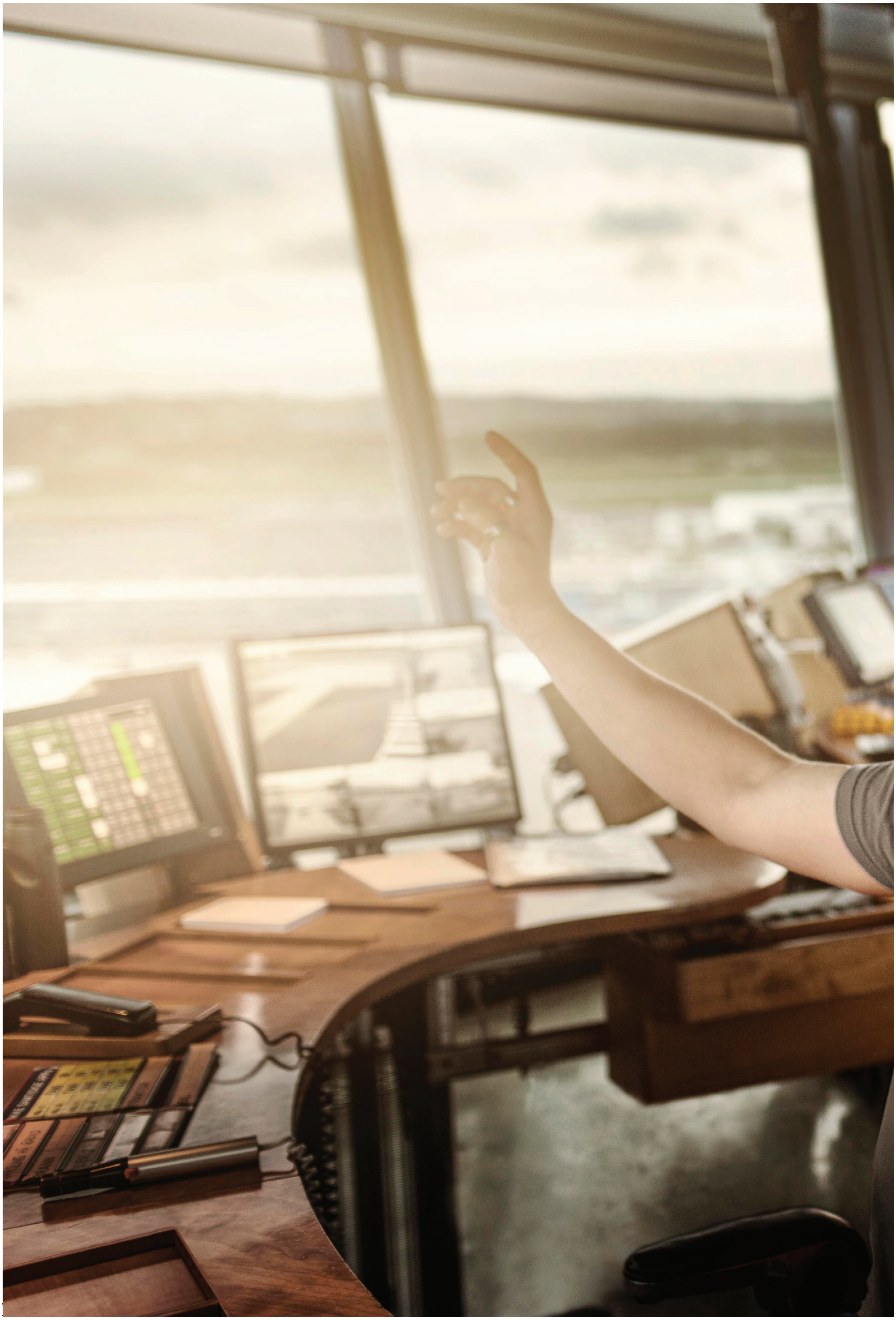
Concept 2: The inner circle indicates the direction by its placement, not being centered. This might be less intuitive than the arrow, however it does not demand any extra objects. It also keep a certain level of uncertainty as it is the diffuse inner circle that indicates the direction. However, a displacement might be less visible than an arrow.



Concept 1



Concept 2



8 Result

Introduction

In this chapter the final solution are presented. The graphic is first illustrated in context of Edda Systems' map. Then the graphic alone is presented including a graphic description. Further the animation of the graphic emerging is statically displayed, the scenario of a Cb emerging is described and the graphics role in the scenario explained. Two future concepts is presented to show how the graphic can adapt to technological developments. Finally, possible challenges involving implementation is described.

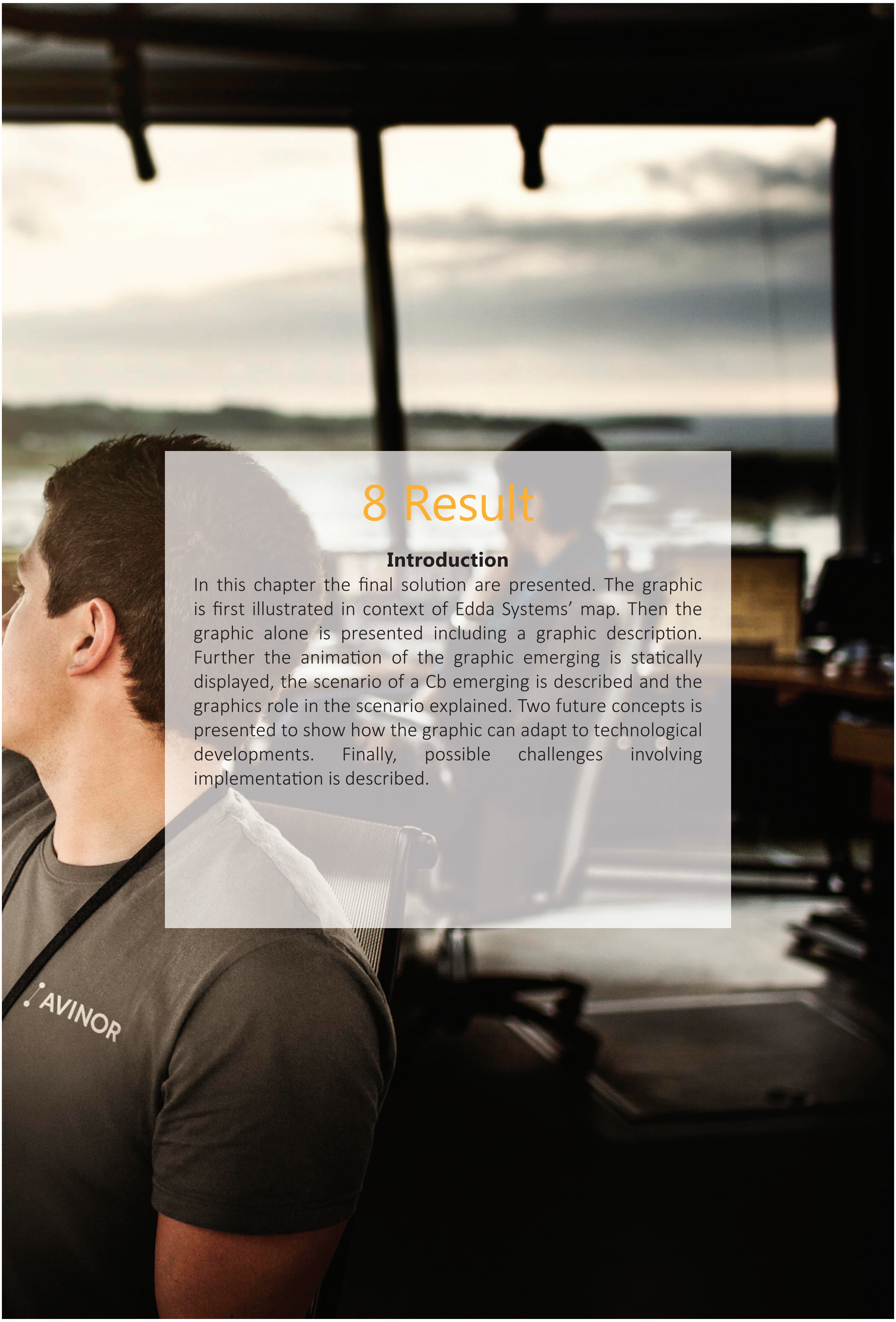
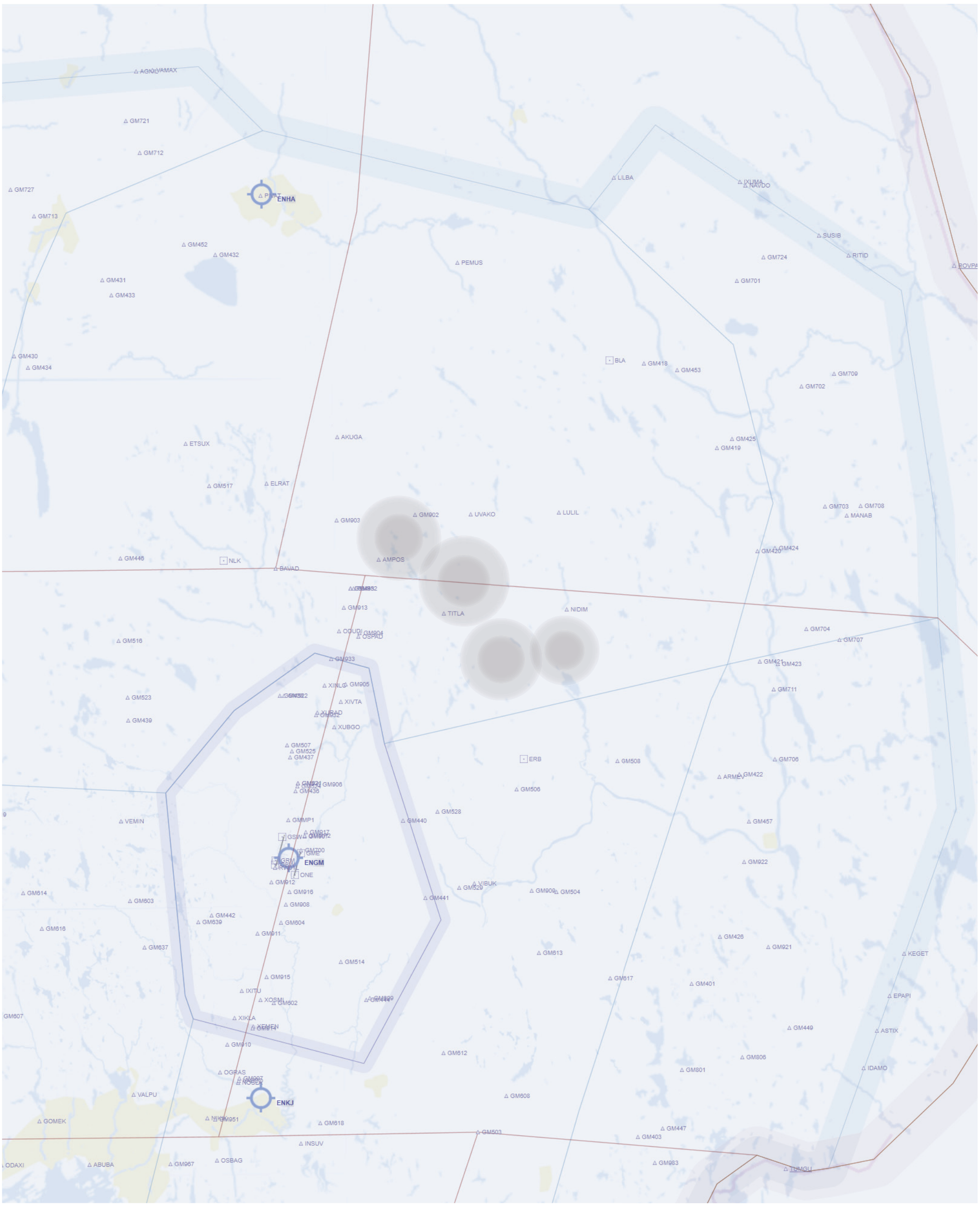


Photo: Avinor

8.1 The Graphic in Context

The Cb-graphic illustrated in a section of Edda Systems' map.

Cb-graphic in context, zoomed in on the graphic.



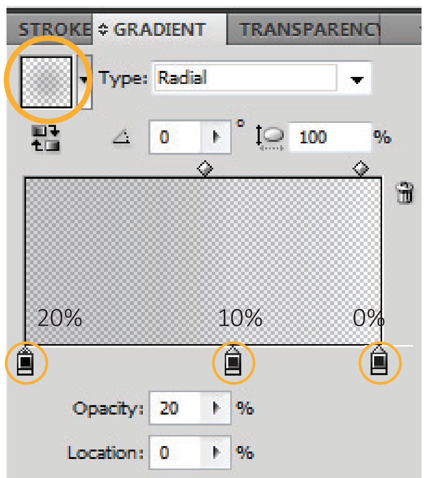
Multiple Cb-graphics, illustrating a “wall” of Cbs

8.2 Graphic Description

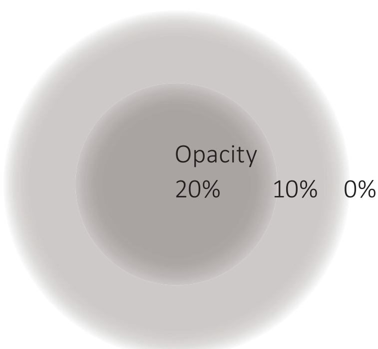
The graphic illustrating Cb-activity is a circle with to levels. The whole element is in one layer to keep the transparency and everything below it sufficiently visible.

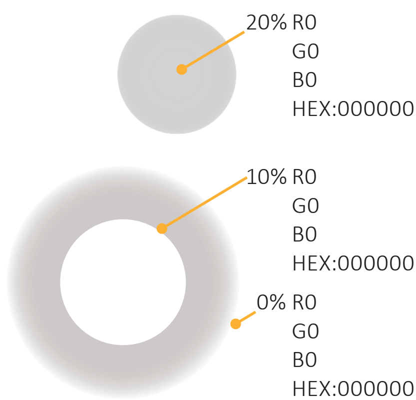
The layers is created of a radial gradient with three gradient sliders with different opacity 20%, 10% and 0%, all with the base color black (R=G=B= 0, Hex:000000). Thus the inner circle is seen as dark grey (opacity 20%) and cover 58,79% of the total circle, in this case. The outer circle is brighter grey, R=G=B=0 and opacity 10%.

Further the assigned color profile is sRGB IEC61966-2.1 (sRGB) as it is one of the most common color working space used in digital work (Colour, 2016). The use of only one base color and sRGB might help decrease calibration errors.



The graphic is created by a radial gradient in black, with three different main opacities; 20%, 10% , 0%.

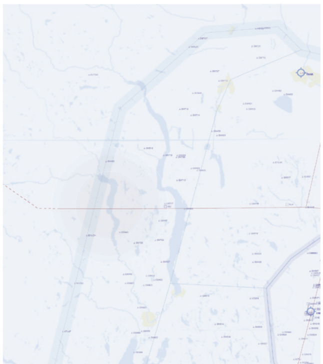




8.3 Animation

The Cb-graphic emerge gradually during 5 seconds. As illustrated above, each picture represent one second passed.

1)
0 Seconds
Nothing is visible

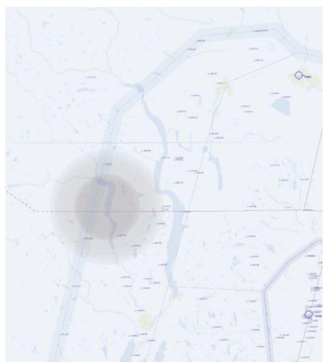


2)
1 Second
The Cb-graphic starts emerging

3)
2 Seconds
The Cb-graphic keeps emerging

4)
3 Seconds

5)
4 Seconds



6)
5 Seconds
The Cb-graphic is done emerging and is fully visible on the screen

8.4 How it Works

1) Weather Information about Cb-activity is registered at MET Norway.

2) Coordinates and intensity is registered.

3) A graphical element is constructed based on intensity and approximately size.

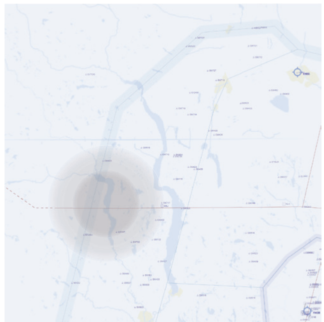
4) The circular Cb-graphic starts to emerge gradually on the ATCOs radar-screen.

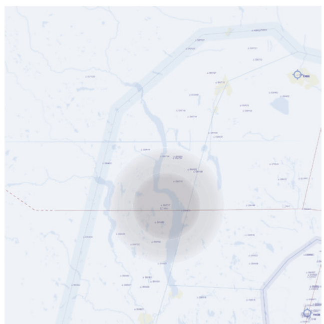
5) After 5 seconds the graphic is finished emerging.

6) The graphic follow the Cbs predicted movement (or in the future, live movement).

7) As the real Cb dissolves, new weather information is provided and the Cb-graphic starts fading away.

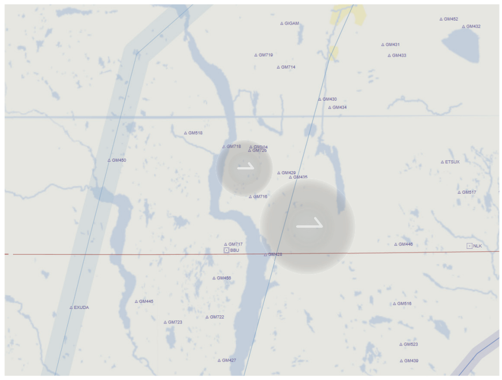
8) After 5 seconds, from the beginning of the fading, the Cb-graphic is gone from the radar-screen.



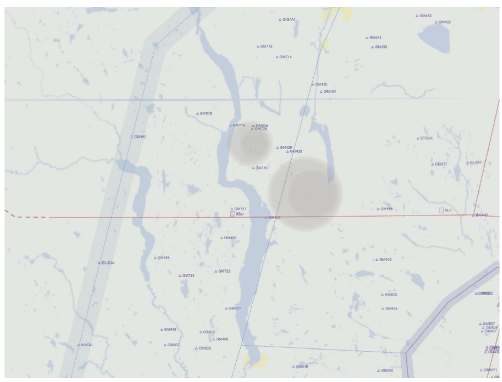


8.5 Future Concepts

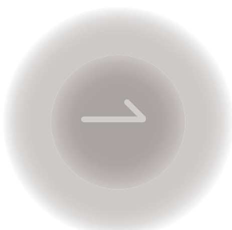
To include possible technological development as well as the ATCOs needs, a main solution and two possible future concepts was developed. Information included in the main solution (presented earlier) is based on existing technology. However, the graphic is created with the technological development in mind. Below, two concepts illustrate possible upgrades by including a direction indicator to enhance the SA level 3. Thus, the solution can be implemented today, but still be relevant and functioning tomorrow.



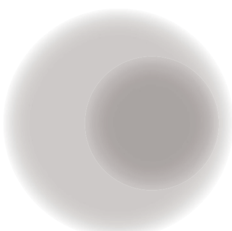
Concept 1: A white arrow is added to the original design to indicate predicted movement. The arrow is white (RGB 255, 255, 255), with an opacity of 50%.



Concept 2: Maintains the original design only here the inner circle is drawn to the direction the Cb is moving.



Concept 1



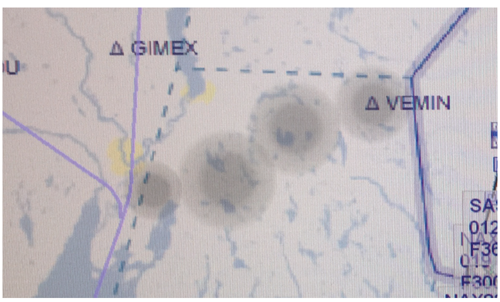
Concept 2

8.6 Challenges

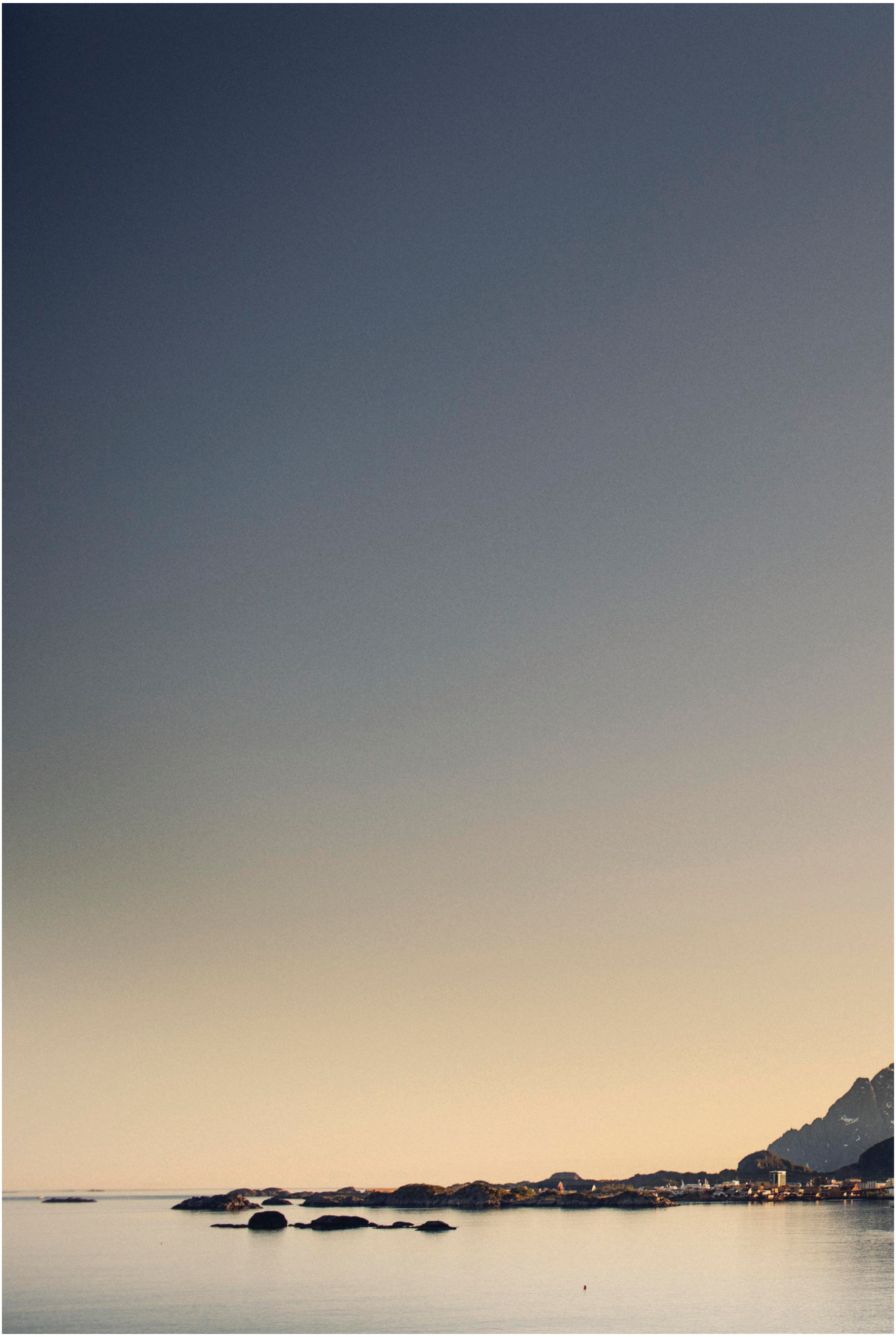
Implementation

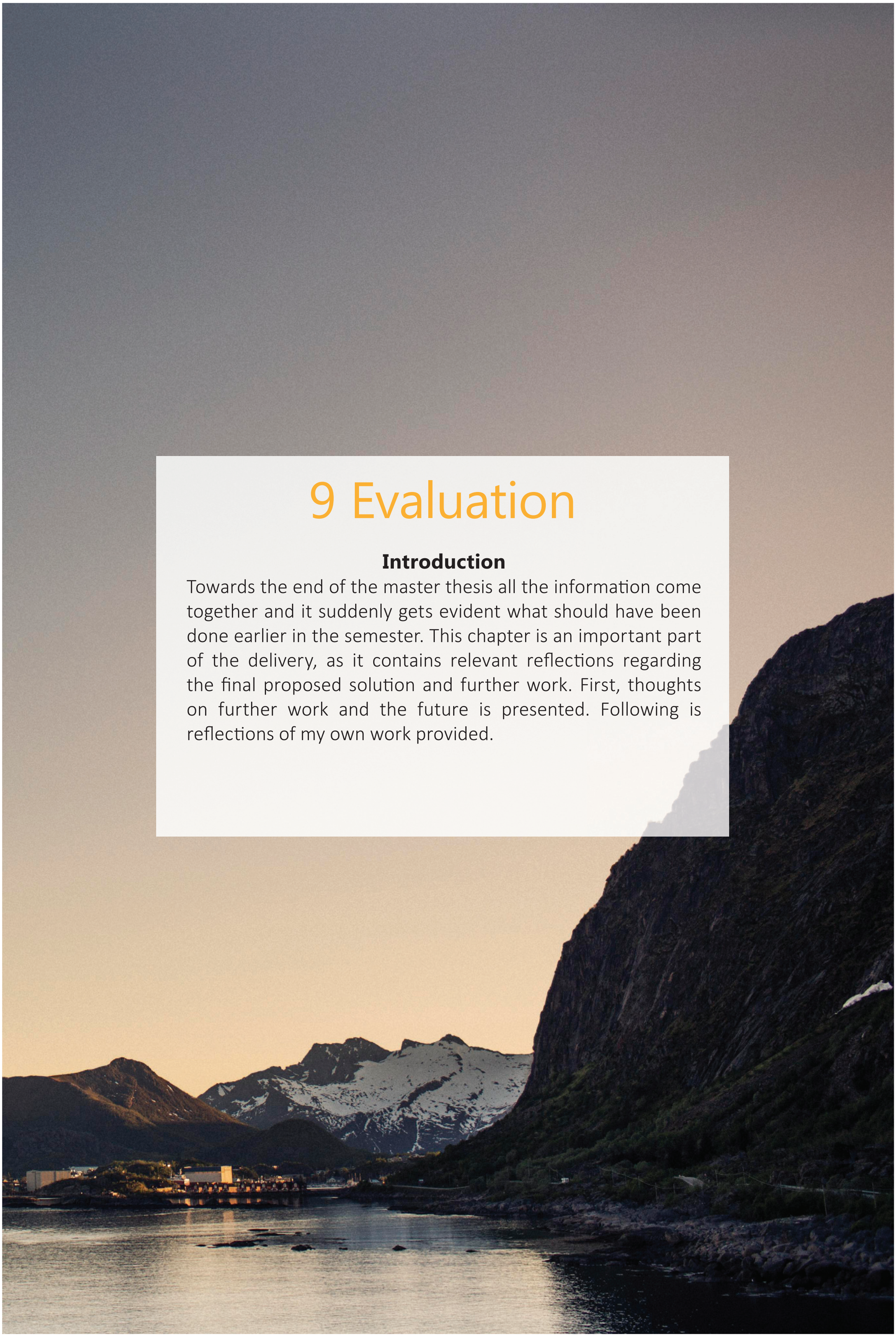
When implementing graphics on different screens it is important to adjust the graphic to the different screen resolution in order to assure e.g. right contrast, brightness. The solution is created in sRGB, a smaller color space, to minimize the error. This is done with the personal adjustment of the screens in mind.

To create a consistent display of the graphic it is important to control the calibration factors such as brightness, color temperature, contrast. The different screens the solution will be implemented on should be characterized and the solution calibrated accordingly. As ATCOs operates on different screen and can adjust their screens based on personal preferences, which can be a comprehensive and challenging job.



Picture of the simulator screen after implementation of the graphic.





9 Evaluation

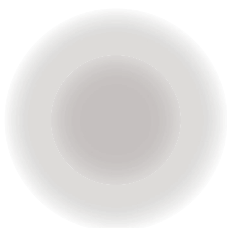
Introduction

Towards the end of the master thesis all the information come together and it suddenly gets evident what should have been done earlier in the semester. This chapter is an important part of the delivery, as it contains relevant reflections regarding the final proposed solution and further work. First, thoughts on further work and the future is presented. Following is reflections of my own work provided.

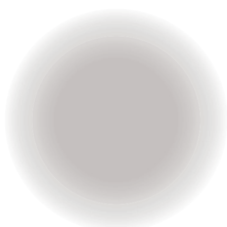
Photo: Avinor

9.1 Future

Technological Development
The graphic was created to follow the technological development. As the accuracy in weather data improves, the inner circle can expand and the outer increase, visualizing less uncertainty. However, the question will be how intense the weather have to be in order to be covered by the inner circle. Further, it might still be valuable to keep the outer circle in order to indicate less intense weather. See illustrations below.



The proposed solution, illustrating graphic with todays uncertainty

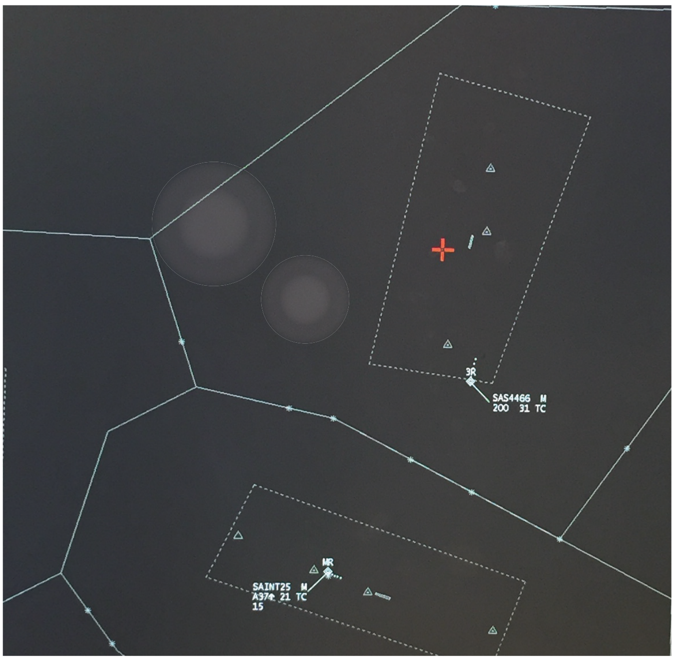


The proposed solution, illustrating graphic with increased certainty.

Generic Solution
The aim was to develop a generic solution for weather information. Even though the final result is tested and presented in Edda Systems GUI, it is developed to maintain the majority of the visibility, due to the shape contrast. An inverted version, switching out the base color black with white might work in NATCONs GUI, as illustrated by the picture on the next page. However, as I did not get the chance to implement and test the solution in NATCONs GUI this is only an assumption and need to be tested and calibrated further. Additionally, the solution on a dark map might need to be darkened, as bright details on dark background can be more visible than dark details on bright background.

A possible further development of the graphic is to use it to illustrate other weather, e.g. all challenging weather. Providing ATCOs with less graphic is a advantage, thus consistency in the graphic displays is a benefit. The proposed solution is not locked to Cb-activity as it illustrates weather intensity, not special features of the Cb-cloud. However, a more accurate indication of wind etc. should be included. Further work should therefore include both ATCOs and MET Norway, in order to discover all necessary data in addition to intensity and accuracy.

The proposed solution on Edda Systems' map



The adjusted, proposed solution on NATCON's map

9.2 Reflection

Methodology

This master thesis have used user-centered design combined with research and theory to discover, define, and develop the project solution. Further, the Interaction Design Research Triangle was used as a way of structure the creative process. Throughout the project, I have moved freely within my methodology. As a designer, it was natural to have a user-centered approach to the problem. It gave a lot of necessary insight about ATCOs and their work. However, focusing on user-needs in a safety restricted discipline has some limitation. If a solution is adapted to the users needs it does not mean that it will be implemented if the safety demands are not accommodated. Further, it was interesting to work with a UCD approach and meeting technological limitation. Thus, without going as far as a technological centered design, the technical limitations had to be taken into account. The result was divided in to a solution for today and concepts aimed at the future.

Combining theory, practical insight and previous experience through the Interaction Design Research Triangle was useful. It helped maintain user needs and safety measures. In order to increase the chance of right use of a solution and thus optimize safety measures, the users have to be involved.

The Layered Scenario Maps was great tools for communicating with users and the four design students. It was useful to have the LSM physical on the wall, so they could be continuously updated with new insight. Especially, since aviation was new to me LSM was useful to get an overview of the discipline but still be able to handle information on detailed level.

Human Factors and Design Theory

The master thesis has given an introduction to human perception and situation awareness. The research phase has been decisive for the project result. However, based on the insight from the field work it seems like human factors is not taken too much into consideration in the development of ATCOs equipment. I mean Norwegian ATC have a potential for improvement when it comes to adapting the workstation to the users and to human factors. There is a balance here, upgrading the ATCOs workstation will cost Avinor, thus Norway might lose their place as one of the more low-priced airspaces. Luckily, the ALMAR-project is up and running, and Avinor have teamed up with new software companies. However, the problems should be solved more in relation to each other not piece by piece.

The Process

It has been a challenging project. Working alone was as instructive as I expected, but also frustrating. The value of sharing your ideas with others really became clear. The input from fellow design students was limited. Especially when working within a discipline few people know much about. Fortunately, I had the opportunity to team up a few times with the 3rd grade students working on a similar project, which was valuable.

As aviation was a new discipline to me, it felt necessary to be exploratory in the discover-phase of the process. Thus, a lot of the work done in this project was to get a comprehensive understanding of aviation, and not targeted towards the focus area. Working with such a unknown discipline was fun and frustrating at the same time. It can be frustrating to spend so much of the projects time learning new things, but on the other side it is really interesting. As I am wrapping up this thesis I am still learning new thing about aviation.

Working with two different GUIs (NATCON's and Edda Systems') was challenging, especially because they were so unlike. As IFE used Edda Systems GUI I had to adapt my solution to their choice in order to enable testing. However, NATCON's GUI is the one used today so in discussion with the user it was most natural to use the current GUI. By introducing concepts on the NATCON GUI first, and then on Edda Systems' it seemed like the necessary feedback was achieved. That my solution had to adapt for a software not implemented nor tested for the ATCOs was a bit confusing. As important graphic in the Edda Systems' test simulator was not decided on before the simulator tests. It might not have affected the results, but it makes it hard to develop a functional graphic regarding contrast and visibility.

Evaluation of the Result

Based on user needs, and IFE's interests a graphic concept was quickly chosen. Ideally I would have looked more into other solutions than a graphic element. A graphic on the radar screen decrease necessary eye movement, and thus can strengthen SA. However, it would have been interesting to go further into the Design Exploration-part of the Interaction Design Research Triangle, and look for more radical solutions.

It has been difficult to work on improving graphic, when the main issue in weather information is the technology, according to the users. However, the discover-phase showed that there are potential of improvements of todays solution, especially as the technology develops. The proposed solution is developed based on todays situation, and the main issue according to the user was the uncertainty in the data. Thus, it is difficult to evaluate if my solution is better or if the inaccurate information overshadows it. Further, if the technology improves it is tempting to believe that the existing solution for weather graphic is too unprecise, and that the proposed solution can add some necessary aspects like visualizing uncertainty and intensity.

The proposed solution is tested in Edda Systems software, thus it has been difficult to find out if the solution can be a decision-aid and decrease reaction time, as such tests not was conducted. However, as relevant theory such as Situation Awareness and apprehension has been consulted in the development, the chances of improving the reaction time should increase.

Improved technology might open more doors than I have anticipated in this thesis, making it possible to indicate e.g. altitude and movement more accurately. Thus, further testing should be done on technological possibilities within meteorology. However, I believe that the developed graphic creates a good base accommodating future technological developments.

Due to color space, calibration and rendition of colors is different from screen to screen and very different in printed media, it is not possible to present the grey tones and contrast of the Cb graphics correctly in paper in this report. A printed version of the result is included in the delivery to illustrate how it looks in Edda Systems software.

Collaboration with Stakeholders

It was inspiring collaborating with so many different people in Avinor, MET Norway, Accident Investigation Board Norway, Civil Aviation Authority Norway, SAS, Norwegian and Bekk Consulting AS, in addition to IFE. I have collaborated with a diverse group of people, which have helped my motivation and reflection throughout the project.

Over all stakeholders have been helpful and positive to the project. However, it is clear that many of the people I have been in contact with is solution oriented. Committed to provide me with an answer more than discuss possibilities. Thus, my interview skills have been tested in order to get the information needed. Further, having more contact with MET Norway would have been interesting in order to look more into their take on future technological possibilities.

Working with such a small, expert group of users has had great impact on the project. Sometime it was difficult to determine if the ATCOs' answers was honest as the pride in fixing things was evident. Additionally, having limited access and time with the users was a challenge. Being in the situation of not having the possibility to reach out to the user at any time was a useful experience. This might be more realistic in "the real world" than we, students, think.

To Conclude

In the beginning of the semester I was afraid that my master thesis was too specific and narrow, not accommodating the demands and size of such a thesis. Then, writing this master thesis I found my self having trouble limiting the information. It has been difficult to sort the content as the project required a thorough and broad insights phase. The discover-phase was long, which shortened the time for specifying the design brief and finalizing the solution. However, I am not sure if it had been better to shorten the insight phase, as I feel most of the information has been valuable to get a holistic understanding of the discipline.

I learned through meeting with users and discussions with my supervisors that a solution, and in this case my project, does not depend on the users meaning or expressed need alone. This is not new information to me, but it can be hard to see when you are in the middle of a project and it seems like no one you meet in the field sees the need of a change. I learned, with a little help from my supervisors that being uncertain in the design process is a good sign. It means that you process the problem, and look out for new unknown solutions. When you are unsure, you might be more open-minded.

It has been challenging planning tasks, evaluate concepts, conduct interviews and deal with stakeholders alone. Furthermore, it has been educational. I could have been better at writing and documenting during the project. In the beginning of the semester I was great at documenting everything, but as different things happened with visits, meeting new stakeholders, more multitasking was required which affected the writing. Looking back on the process there are several things I think could have been done differently. My result is only one of many possible solutions. Further work would have, amongst others, included testing of the possible future concepts. Also having more contact with MET Norway to discuss possible future scenarios of the technological development would have been interesting.

During the project it has been fun exploring a new discipline, especially as it gave me an excuse to sit in the cockpit of a plane. I have learned a lot about conducting interviews, observation, take good notes from such sessions, handle and structure a lot of information, and acquire new design methodology such as Layered Scenario Mapping. Further, I have learned the value of sharing knowledge with others and especially sharing design-thoughts with non-designers. I find my experiences from the project valuable for my future work, and look forward to build further on my knowledge and experience.

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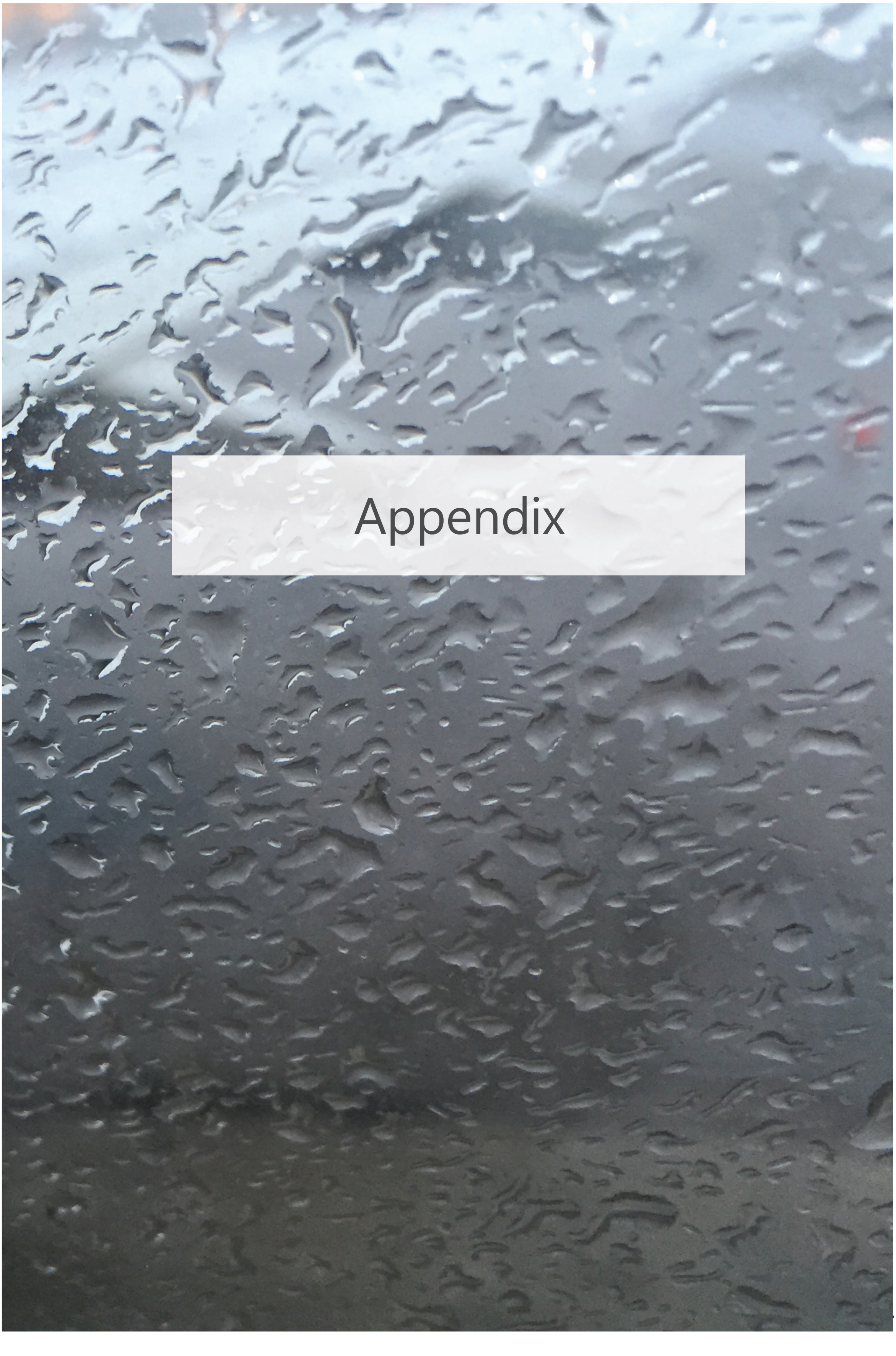
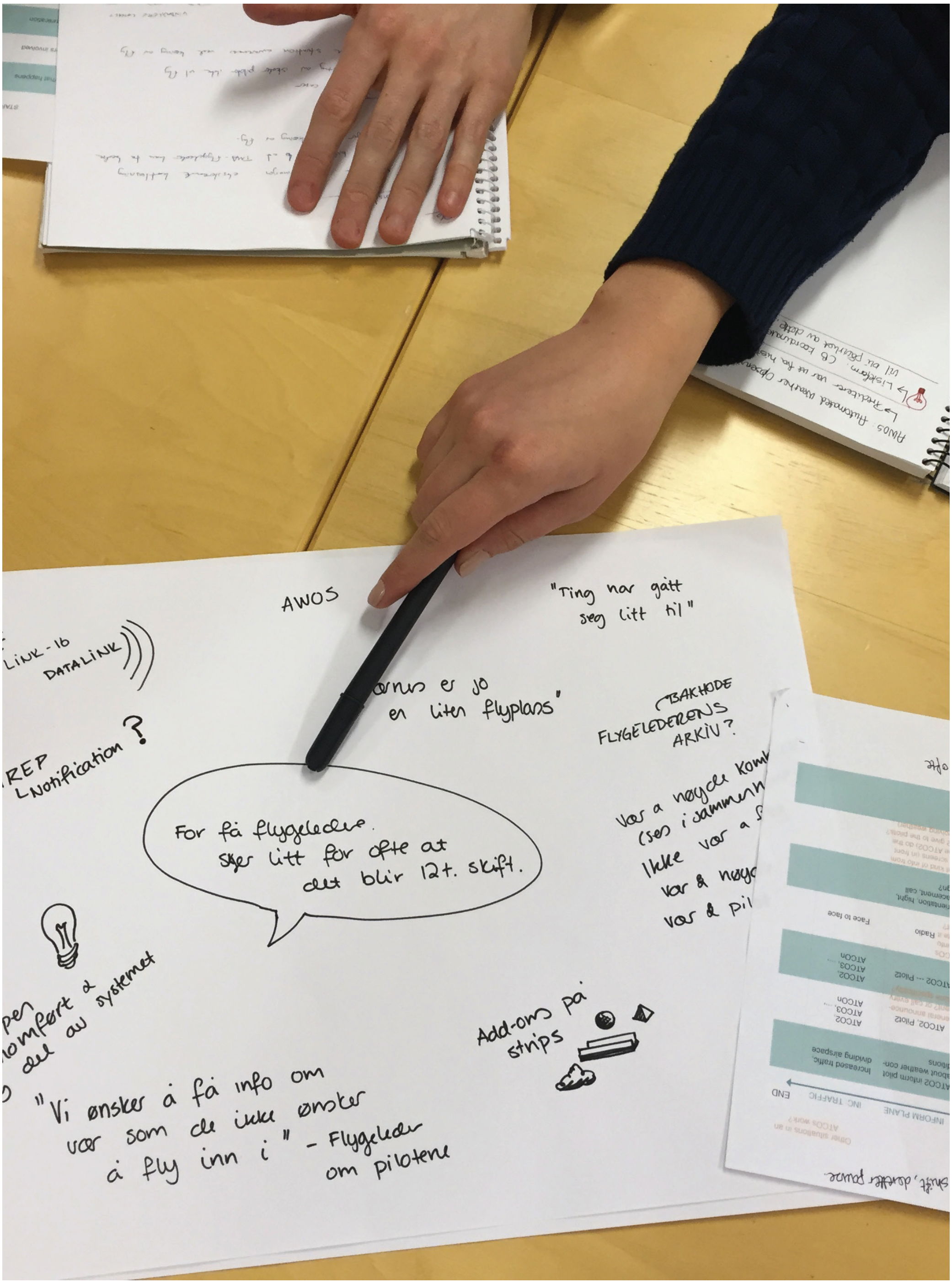
All pictures are taken by the author unless it is stated otherwise.



Appendix

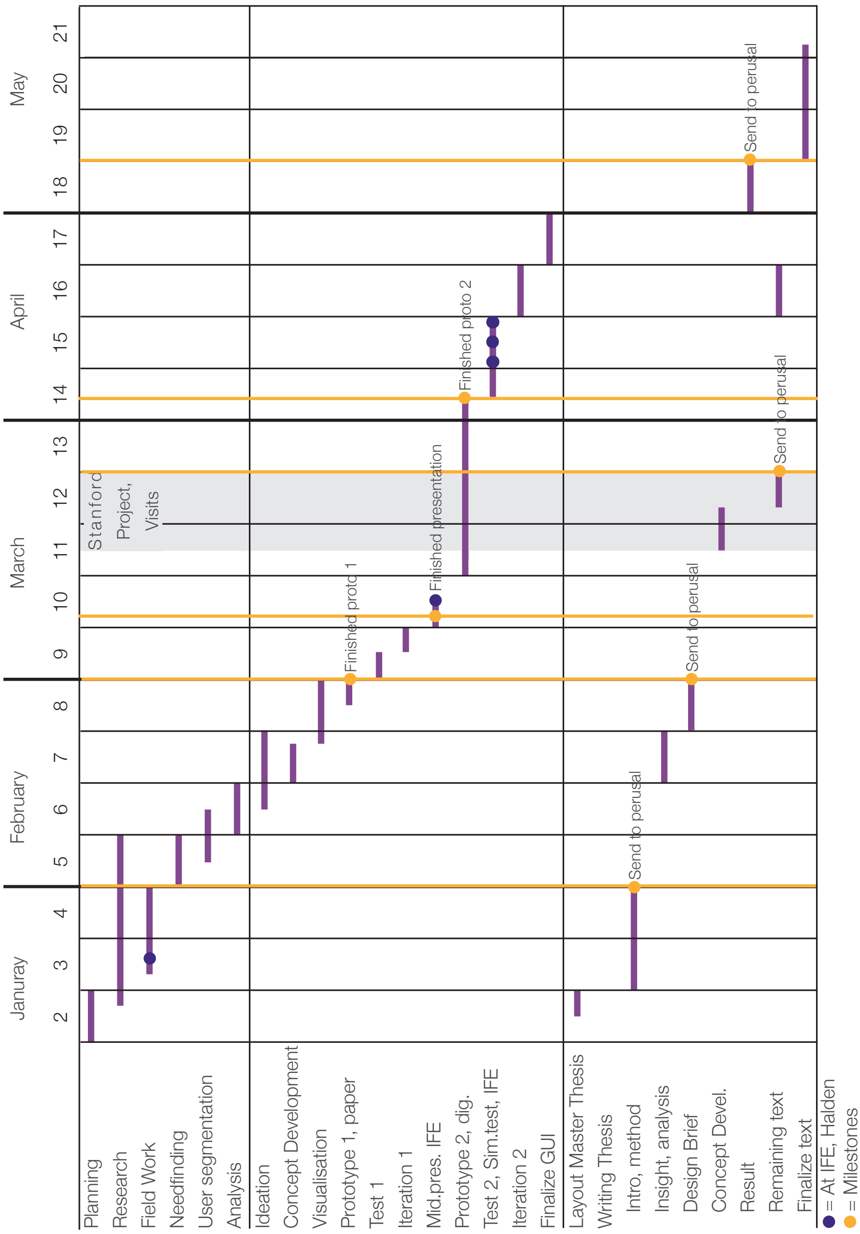
Table of Content



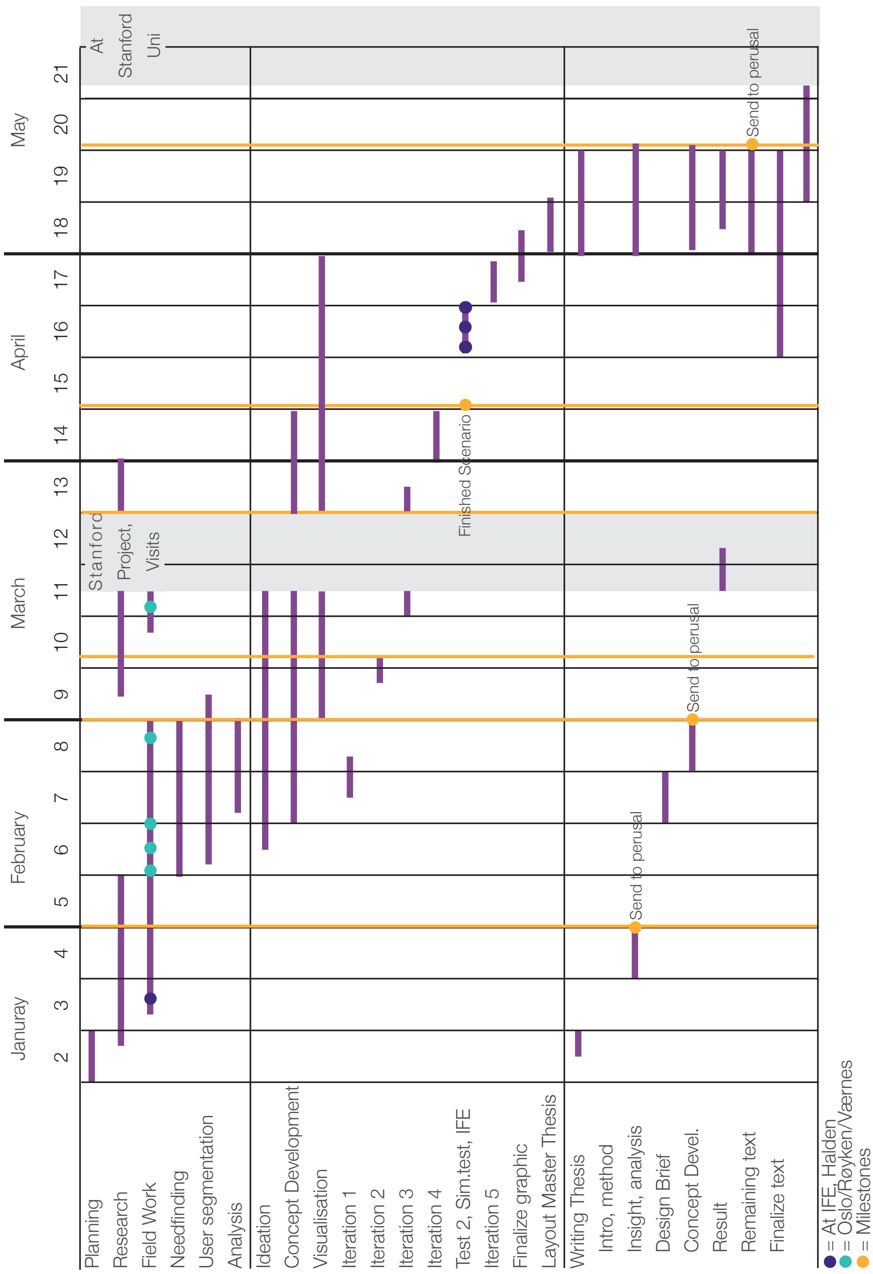
Picture from LSM workshop with 3rd grade students.

Gantt

The first and the last Gantt diagram.



The first Gantt



The final Gantt

Activity Log

All meetings, interviews ect. conducted during the project. All meetings with my supervisors are not included.

Activity log

When	What	Who		Where
05.01.16	Meeting	Alf Ove Braseth	Dr. Philos, IFE	Skype/Asker
07.01.16	Meeting	Trond Are Øritsland	Prof. IPD, NTNU	IPD, NTNU
08.01.16	Meeting	Trond Are Øritsland	Prof. IPD, NTNU	Skype/IPD, NTNU
		Alf Ove Braseth	Dr. Philos, IFE	
		Christian Raspotnig	Ph.D., IFE	
15.01.16	Meeting	Trond Are Øritsland	Prof. IPD, NTNU	IPD, NTNU
20.01.16	Meeting	Alf Ove Braseth	Dr. Philos, IFE	IFE, Halden
	/safari, intro	Christian Raspotnig	Ph.D., IFE	
		J. E. Simensen	M.Sc., IFE	
		H. O. Randem	M. Sc., IFE	
		Gyrd Skraaning jr.	Dr. Philos	
03.02.16	Phone call	Meteorologiske institutt		Phone/Trondheim
06.02.16	Observation	SAS flight		In cockpit TRD – OSL
	Interview	NN	Captain	
		NN	Co-pilot	
09.02.16	Meeting and	Marit Louise Howell		ACC Røyken
	observation	Togeir Slotten		
		Alf Ove Braseth		
		Christian Raspotnig		
		NN	Supervisor, Avinor	
10.02.16	Meeting	Fredrik Matheson	BEKK	BEKK, Oslo
11.02.16	Meeting	Lars Kristian Flem	Kreativ leder, BEKK	BEKK, Oslo
11.02.16	Meeting	Hilde Johannessen	BEKK	Oslo
15.02.16	Observation	In-training Captain	Norwegian flight	In cockpit OSL – TRD
	Interview	Captain (Functioning as co-pilot)		
		Pilot (Captain in training)		
17.02.16	Meeting	Alf Ove Braseth	Dr. Philos, IFE	IPD, NTNU
		Christian Raspotnig	Ph.D., IFE	

22.02.16	Meeting	Trond Are Øritsland	Prof. IPD, NTNU	IPD, NTNU
22.02.16	Workshop	3.klasse-studentene Forberedelse til besøk Værnes, Layered Scenario Mapping.		IPD, NTNU
25.02.16	Observation	NN	Operative sjef, Avinor	Avinor, Værnes
	Interview	NN	Flygeleder TWR/APP	
		Nils Fremstad	Flygeleder/Fagspes	
		NN	Driftsansvarlig Systemdrift	
		NN	Supervisor, tidl. flygeleder	
29.02.16	Meeting	Trond Are Øritsland	Prof. IPD, NTNU	IPD, NTNU
29.02.16	Workshop	3.klasse-studentene Bearbeiding av innsikt – Justering av LSmapping		IPD, NTNU
02.03.16	Meeting	Alf Ove Braseth	Dr. Philos, IFE	Skype/Trondheim
03.03.16	Conversation	NN Luftfartstilsynet	Rådgiver, analyse	Tlf/Trondheim
03.03.16	Conversation	NN Statens havarikommisjon for transport	Havariinspektør, SHT	Tlf/Trondheim
14.03.16	Meeting	Trond Are Øritsland	Prof. IPD, NTNU	IPD, NTNU
14.03.16	Coordination	Hans Olav Randem Starting to plan implementation. Clarification of requirements and expectations.	IFE	eMail/Trondheim
17.03.16	Focus group	Nils Fremstad	Flygeleder/Fagspes	Avinor/Værnes
		NN	Flygeleder	
		NN	Flygeleder u/opplæring	
01.04.16	Meeting	Alf Ove Braseth	Dr. Philos, IFE	Skype/Trondheim
04.04.16	Meeting	Thomas Porathe		IPD, NTNU
06.04.16	Meeting	Alf Ove Braseth	Dr. Philos, IFE	Skype/Trondheim
06.04.16	Conversation	Christian Raspotnig		Tlf/Trondheim
18-22.04.16		Alf Ove Braseth	Dr. Philos, IFE	IFE, Halden
		Christian Raspotnig	Ph.D., IFE	
		J. E. Simensen	M.Sc., IFE	
		H. O. Randem	M. Sc., IFE	
		Gyrd Skraaning jr.	Dr. Philos	
21-22.04.16	Sim.testing	NN	Flygeleder, Avinor	IFE, Halden
		NN	Flygeleder, Avinor	IFE, Halden
		NN	Flygeleder, Avinor	IFE, Halden
		NN	Flygeleder, Avinor	IFE, Halden

Semi-structured inteview

The script used during contextual semi-structured interviews. The questions was meant as guidelines to the interview, and was not strictly followed except for some key-questions. The goal was to get the participant to talk freely to get greater insight in the profession and the work environment.

Flygeledere:

Kan jeg ta bilder? Informasjonen vil bli brukt i offentlig masteroppgave. Er dette i orden for deg? Kan anonymisere info.

Hvor lenge jobber de per skift? Hvor mange skift i uken?

- Kontrollerer dere approach i tillegg til en-route eller fordeler dere dette med tårnet?
- Hvilke instrumenter forholder du deg mest til?
    - ~~Er dette levert av Edda Systems? (*Ok for IFE at jeg nevner dette?*)~~
      Answer: Learned that NATCON was used on all control centrals, and Edda Systems solution was used in a training simulator.
    - Justerer du utstyret og skjermene noe etter personlige preferanser når du tar over?
- Hva får du av vær-informasjon før og underveis i skiftet?
    - Kommer all vær-informasjon fra MET Norway?
    - Hvordan forholder du deg til det og bruker denne infoen?

- Hvor nøyaktig mener du at denne infoen er?
- Stemmer det at kun cumulonimbus og towering cumulus blir informert om?

- Hva gjør du hvis en Cb er i luftrommet ditt, forventet og uforventet(?) ?
  - Hvem forholder du deg til?
  - Ønsker du uansett å navigere rundt en Cb, samme hvilken størrelse for eksempel?
- Hvis du kunne bestemt, hva hadde vært optimalt å ha av utstyr og informasjon i forbindelse med Cb?
  - Hvordan skulle du ønske å bli varslet og motta informasjon om Cb?
- Hva liker du best med det å være flygeleder?

Spørsmål piloter og flygeledere
Cumulonimbus

Piloter:
Kan jeg ta bilder? Informasjonen vil bli brukt i offentlig masteroppgave. Er dette i orden for deg? Kan anonymisere info.

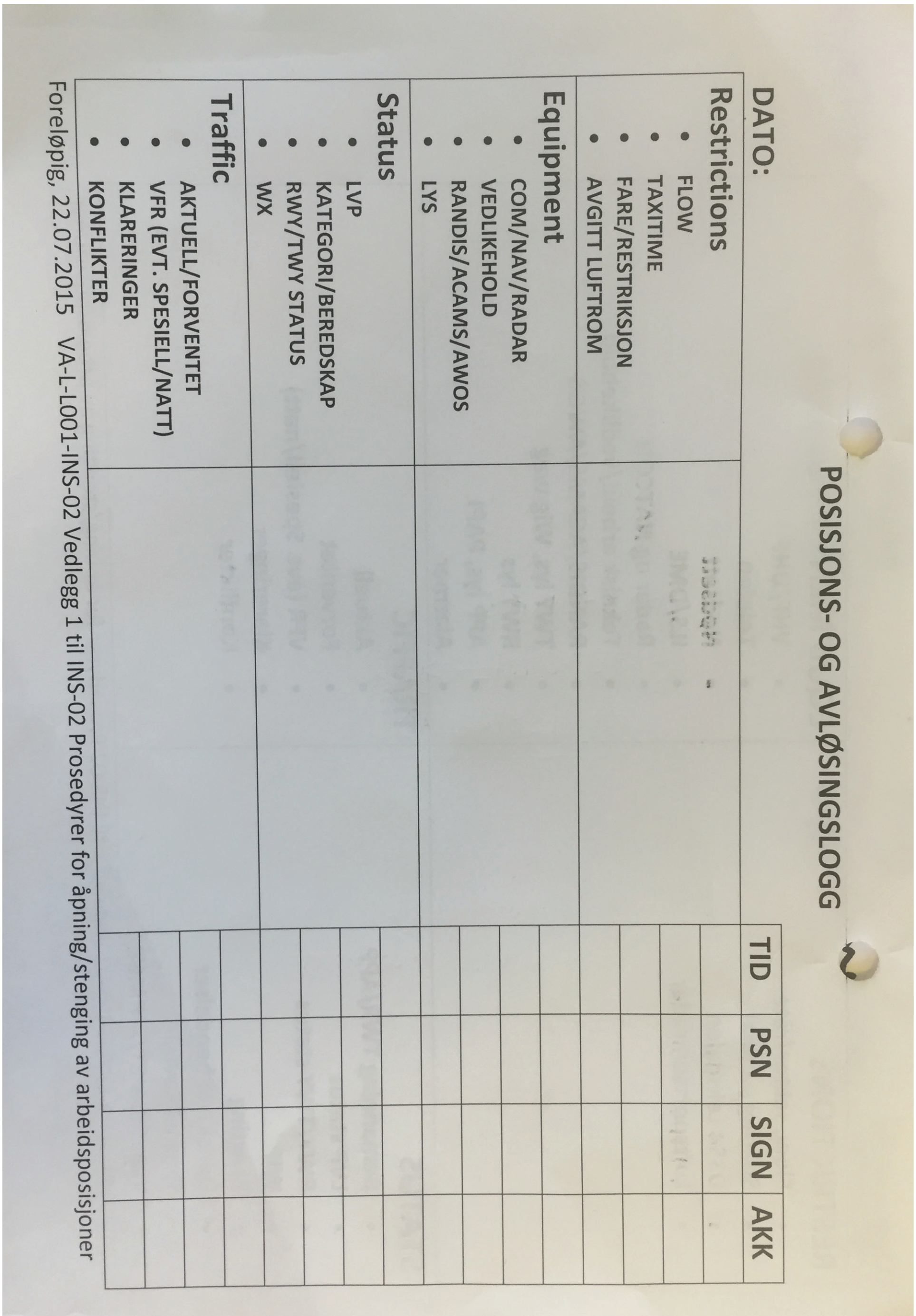
- Hva får du av vær-informasjon før take-off?
    - Hvordan forholder du deg til denne vær-infoen?
    - Hvor nøyaktig mener du at den er?
    - Stemmer det at kun cumulonimbus og towering cumulus blir informert om?
- Hva gjør du før, under og etter flygningen?
- Hvilke utstyr bruker du? (hva heter det?)
    - Hvilke utstyr forholder du deg mest til? (bruker mest)
    - Er det stor forskjell på utstyret mellom flytyper?
- Hva gjør du hvis du får øye på en Cb, uforventet?

- Flyr dere over, gjennom, under, rundt?
- Hva er det mest utfordrende med Cb?
- Kan de være vanskelig å oppdage for dere? Har det kommet brått på?

- Hvem forholder du deg til når Cb oppstår?
- Hvordan er kommunikasjonen med flyvelederene?
  - Hva er den viktigste infoen dere får fra flyvelederne?
  - Hender det at dere snakker forbi hverandre?
  - Får dere informasjon om Cb fra flyveledere, eller gir dere mest informasjon om det til dem?
- Hvis du kunne bestemt, hva hadde vært optimalt å ha av utstyr og informasjon i forbindelse med Cb?
  - Hvordan skulle du ønske å bli varslet får informasjon om Cb?
- Hva liker du best med det å være pilot?

Notepad

Bellow, Værnes standardized “notepad” is presented. After a lot of note taking, they found it necessary to create a scheme all ATCOs could/should use.


POSISJONS- OG AVLØSINGSLOGG

DATO:

Restrictions
- FLOW
- TAXITIME
- FARE/RESTRIKSJON
- AVGITT LUFTROM

Equipment
- COM/NAV/RADAR
- VEDLIKEHOLD
- RANDIS/ACAMS/AWOS
- LYS

Status
- LVP
- KATEGORI/BEREDSKAP
- RWY/TWY STATUS
- WX

Traffic
- AKTUELL/FORVENTET
- VFR (EVT. SPESIELL/NATT)
- KLARERINGER
- KONFLIKTER

TID	PSN	SIGN	AKK

Foreløpig, 22.07.2015 VA-L-L001-INS-02 Vedlegg 1 til INS-02 Prosedyrer for åpning/stenging av arbeidsposisjoner

RESTRICTIONS

- Flow, sektor/rate
- Spacing på final
- D354 Leksdalen
- Luftsportsområder

EQUIPMENT

- VHF/UHF
- Telefon
- Nødsett
- ILS/DME
- Radar og NATCON
- Teknisk arbeid/vedlikehold
- RANDIS/ACAMS/AWOS
- TWY lys, Wig wag
- RWY lys
- APP lys, PAPI
- Alarmer

STATUS

- Bemanning TWR/APP
- LVP status
- RWY/TWY status
- WIP
- Brøyting
- Uønskede hendelser
- Spesielle avtaler
- Vær/SIGMET/AIRMET

TRAFFIC

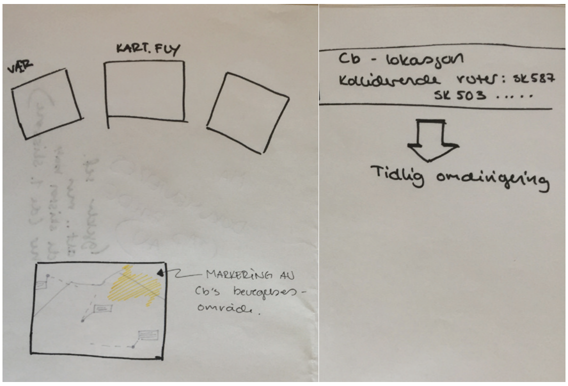
- Aktuell
- Forventet
- VFR (evt. Spesiell/natt)
- Klareringer
- Konflikter

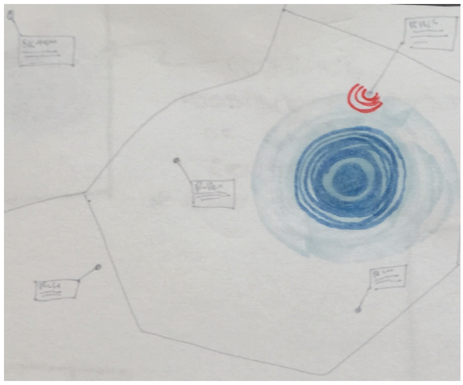
13.11.2014 VA-L-L001-INS-02 Vedlegg 1 til INS-02 Prosedyrer for åpning/stenging av arbeidsposisjoner

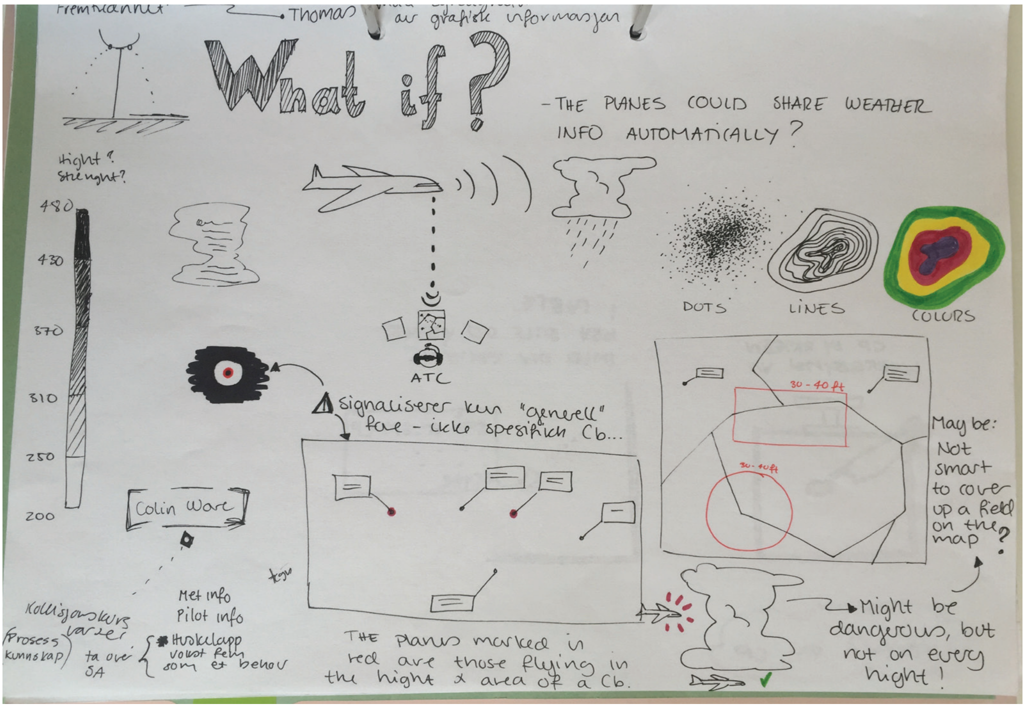
Sketches

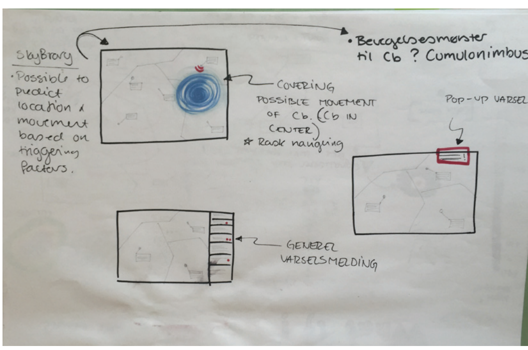
A more comprehensive sample of sketches. From rough paper sketches, to digital sketches on both NATCON's map, and Edda Systems' map.

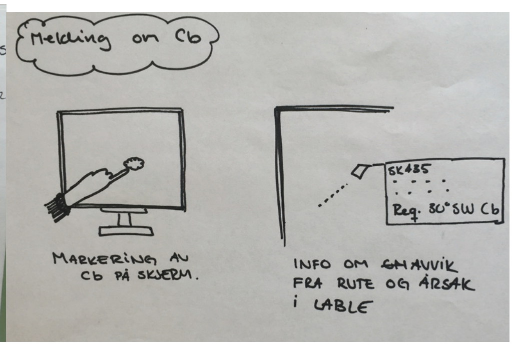
Paper sketches, Early ideation phase



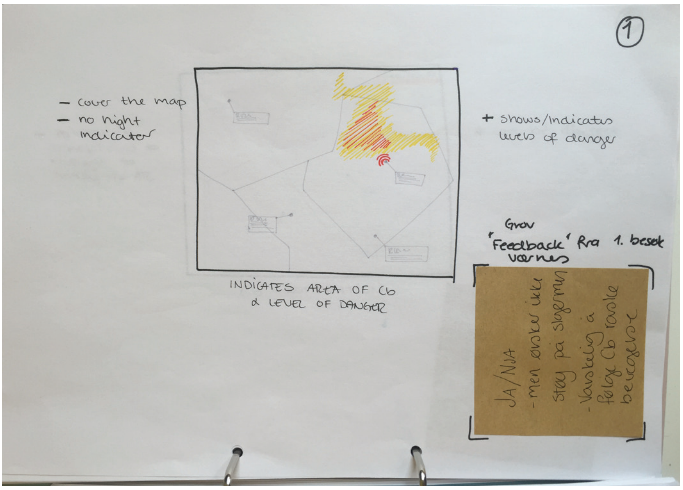


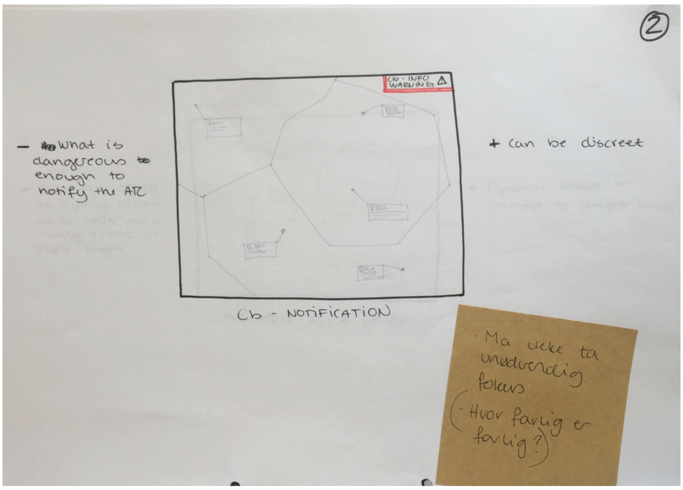


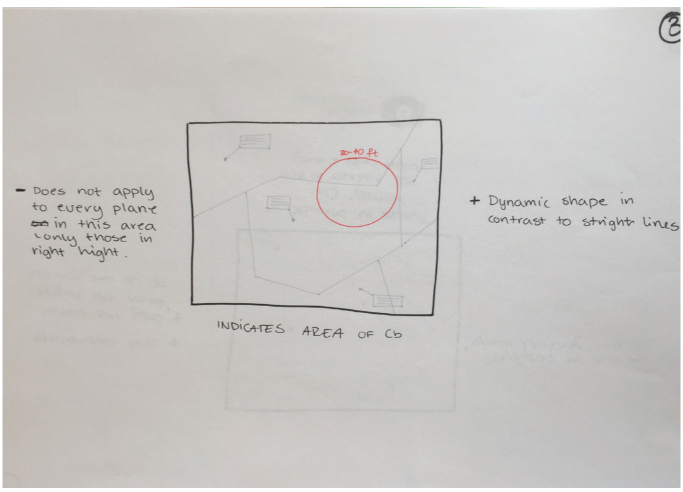


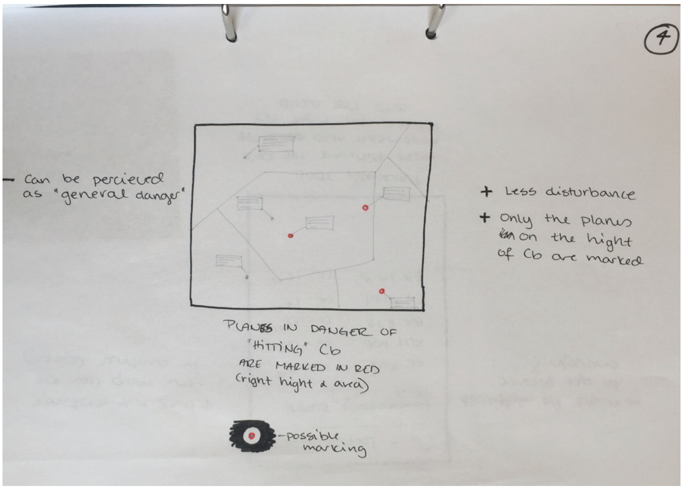


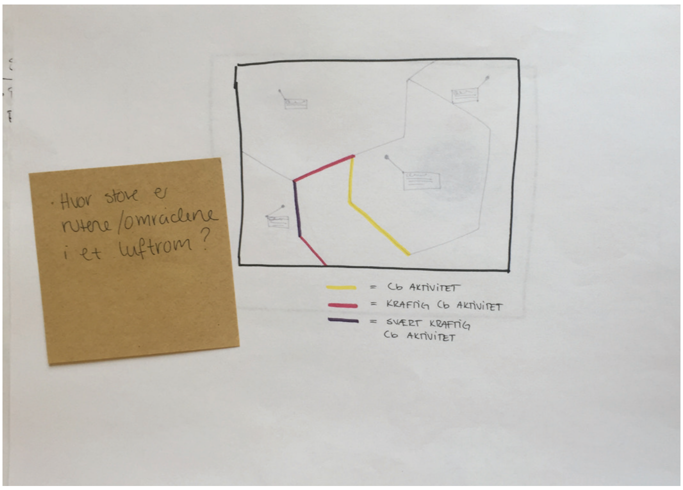
Paper sketches, Early ideation phase

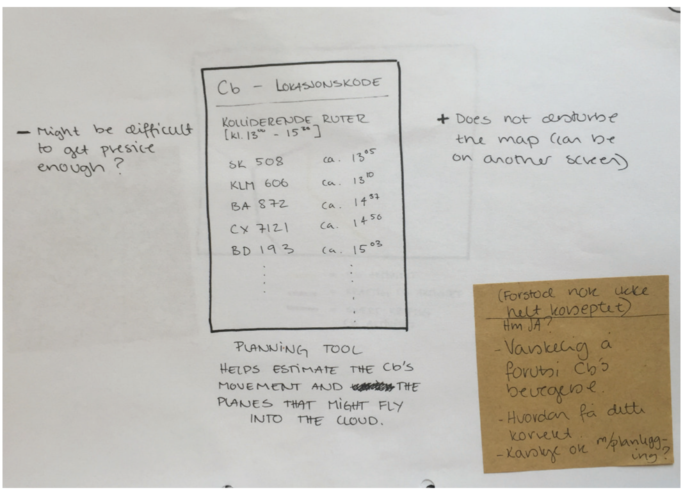




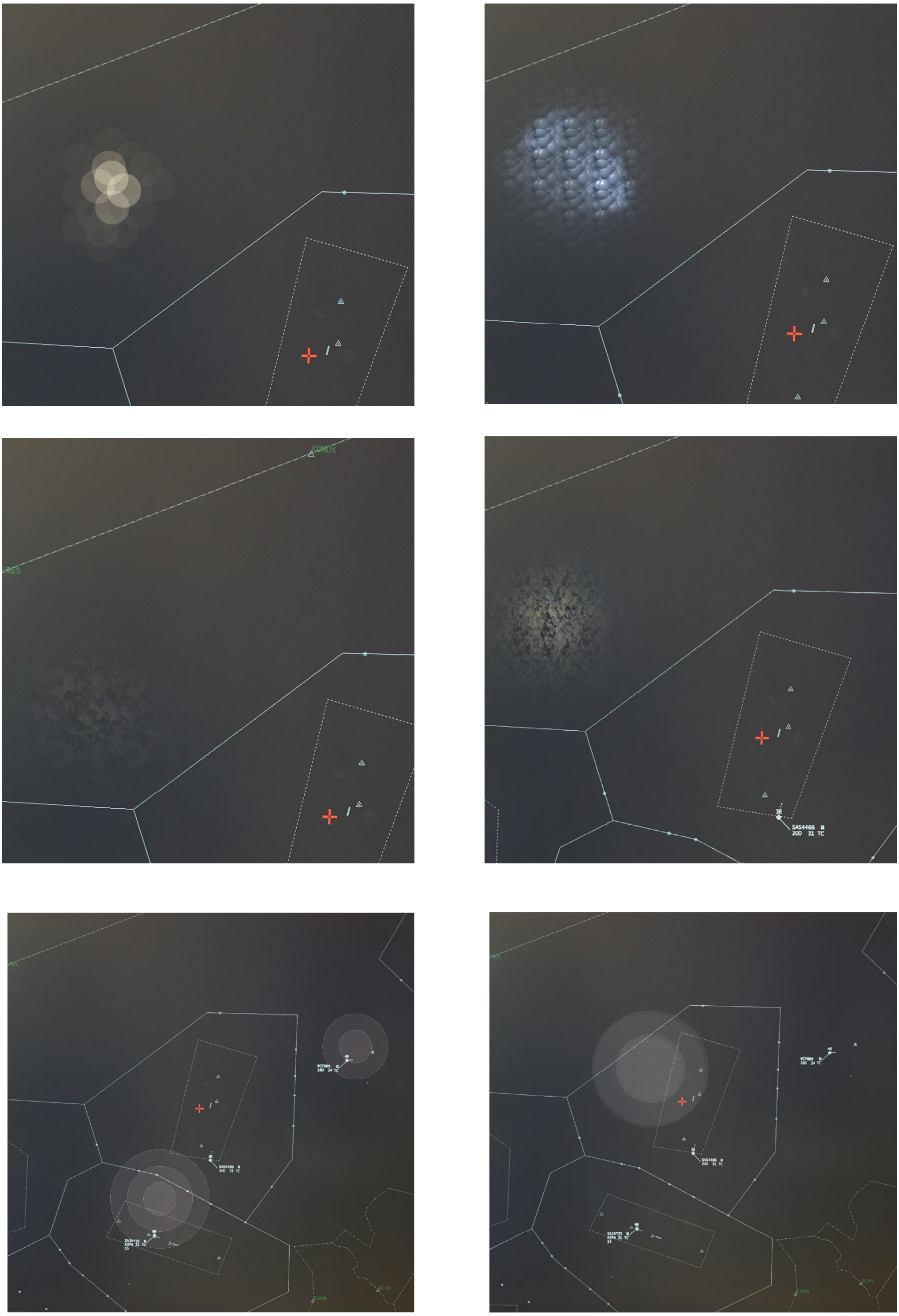



4
- Can be percieved as "general danger"
+ Less disturbance
+ Only the planes on the hight of Cb are marked
PLANES IN DANGER OF 'HITTING' Cb ARE MARKED IN RED (right hight & area)
possible marking

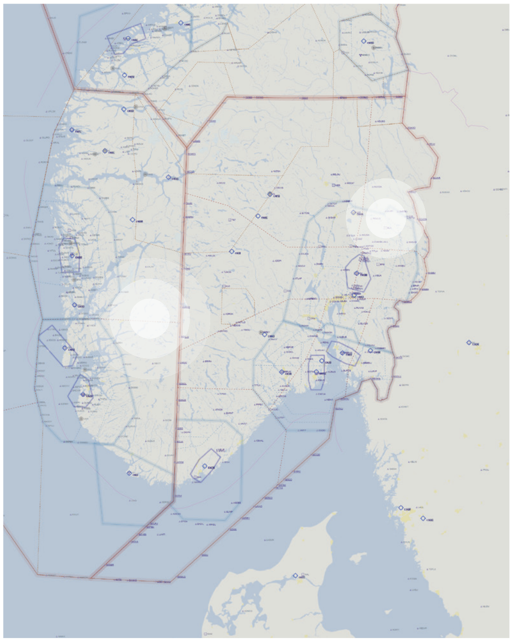

· Hvor store er rutene/områdene i et luftrom?
= Cb AKTIVITET
= KRAFTIG Cb AKTIVITET
= SVÆRT KRAFTIG Cb AKTIVITET


- Might be difficult to get presice enough?
Cb – LOKASJONSKODE
KOLLIDERENDE RUTER [kl. 13^{00} - 15^{00}]
SK 508 ca. 13^{05}
KLM 606 ca. 13^{10}
BA 872 ca. 14^{37}
CX 7121 ca. 14^{56}
BD 193 ca. 15^{03}
+ Does not disturbe the map (can be on another screen)
PLANNING TOOL
HELPS ESTIMATE THE Cb'S MOVEMENT AND THE PLANES THAT MIGHT FLY INTO THE CLOUD.
(Forstod nok ikke helt konseptet)
Hm JA?
- Vanskelig å forutsi Cb's bevegelse.
- Hvordan få dette korrekt.
- Kanskje ok m/planlegging?

Digital sketches, NATCON map

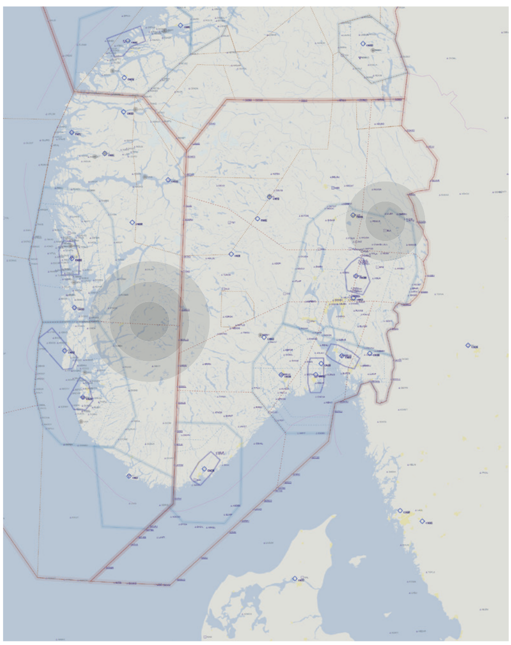


Evaluation of Digital sketches, Edda Systems’ map.



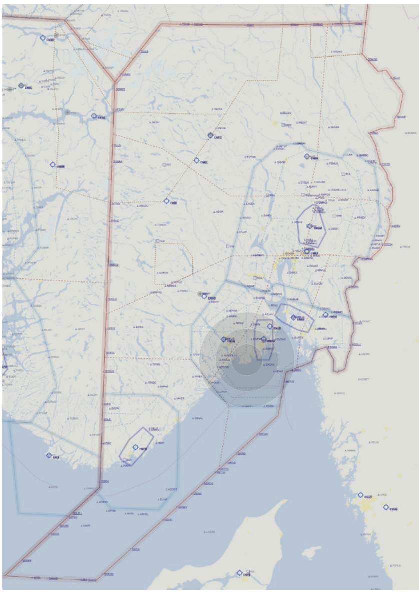
Too bright, almost not visible. Indicates that the Cb is placed within the inner circle.

1



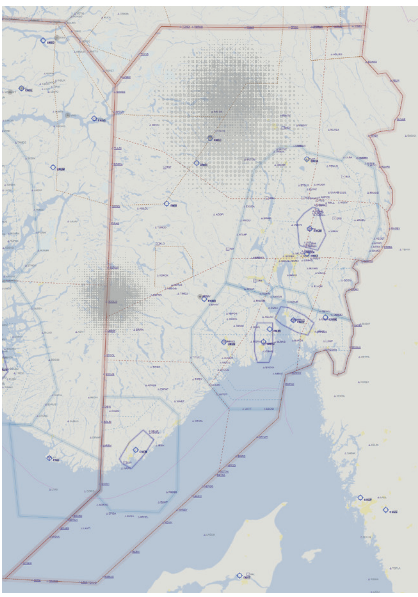
More visible than the white (picture 1). Same problem as with picture 1; the inner circle seem to be the center.. but maybe it is, or is it wrong?
The “clean” shape of the circles is more calm, predictable and less messy than asymmetric shapes. The eye do not need a long time to see the contrast to the straight lines and recognize the well known circle.

2



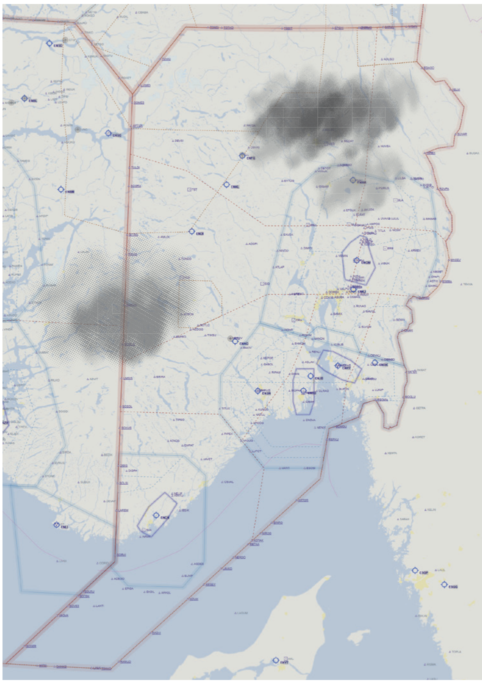
See picture 2 Same feedback as picture 2.

3

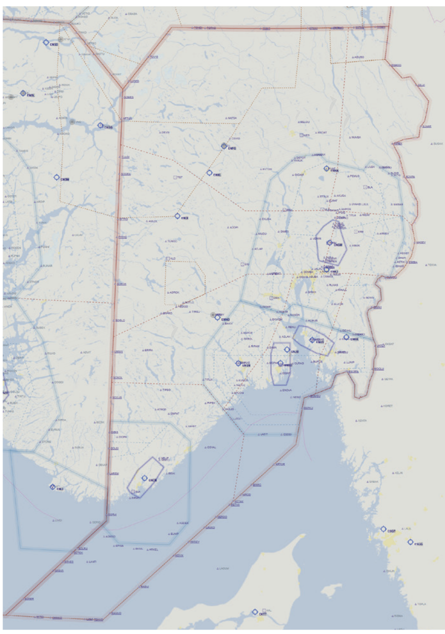


A more diffuse version of picture1-3. Visualize the uncertainty in the data, are less visable and need a higer opasity - which makes the clouds less transperent. This can cover up other information.

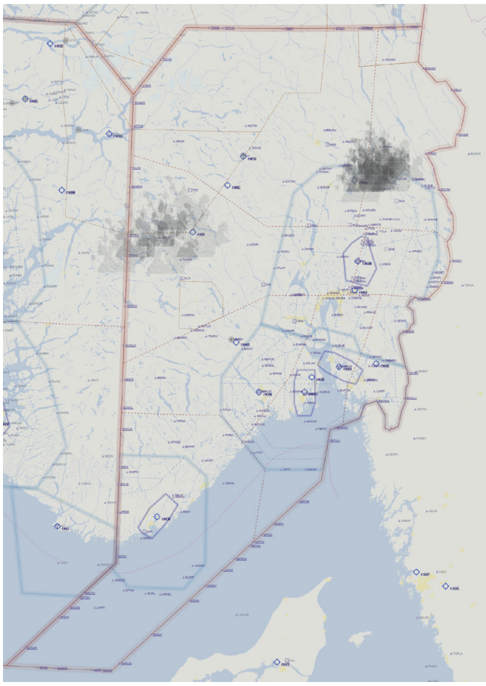
4



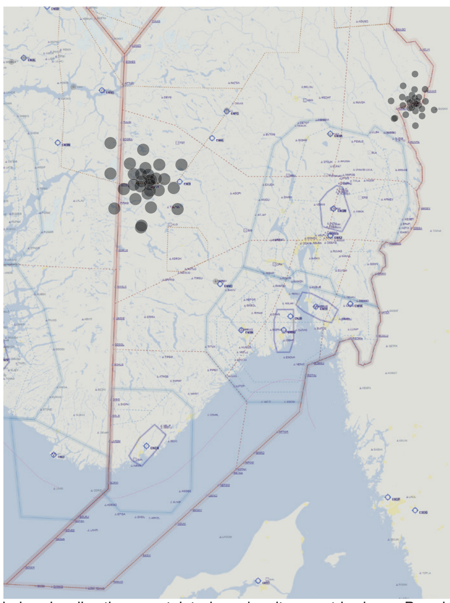
Can remind of clouds, might be easier to understand that it is information about clouds. At the same time it might be percieved as caricatured, and therefor a bit un-serious.



Comunicates “cloud” through the shape. Might have some of the same problems as picture 5, and also the same opasity-problem as picture 4.



This offers a more line-based shape. It might help highlight the uncertainty. All the lines overlapping can be confusing and messy. There are alot of lines for the eye to follow and are messy together with the map and its lines.



This helps visualize the uncertainty, based on it asymetric shape. By using the concervative circle shape impression is made more settle, but there is still a dynamic and asymetric composition. The circles can give an impression of being single clouds, even though that might not be correct, it still communicates where the Cb are at the strongest.

But, the pilots want to go around anyway, so is it really important to show where the Cb is at its strongest?

8

Conspicuity Index Method: Results

Bellow is the results from the Conspicuity Index Method. First, each result for each sketch (B1, B2, B3, B4) is presented in the tables. The next page show the results from the calculations, this is also presented in the thesis text. P1-P5 is the different persons tested.

B1

	Right 1	Right 2	Right 3	Left 1	Left 2	Left 3
P1	50,5	50,5	54,5	40,9	40,9	45
P2	34,6	34,7	33,5	25	24,3	23,2
P3	48,9	50	51,2	45	45,5	46,4
P4	43,4	44	45	34,4	34	32,7
P5	47,5	54,3	54,9	46,4	48,8	50,5

B2

	Right 1	Right 2	Right 3	Left 1	Left 2	Left 3
P1	34	35,3	35	31	32,3	32,5
P2	19,3	21	22,4	19,5	18,7	18,4
P3	38,1	43,2	47,4	40	44,5	45,8
P4	28,5	35,5	36,9	33,6	32,1	31,4
P5	51,6	52,6	54,6	49,6	51	51

B3

	Right 1	Right 2	Right 3	Left 1	Left 2	Left 3
P1	39,9	40,4	42,5	40,6	41,4	42,4
P2	31,9	32,2	32,4	24,7	26,4	27,4
P3	49,1	51,5	55,5	37,8	47,8	54,8
P4	43,1	43,7	47,6	33,3	32	30,6
P5	49,2	53,3	55,9	44,4	48,1	52,1

B4

	Right 1	Right 2	Right 3	Left 1	Left 2	Left 3
P1	35,9	36,5	37	34,7	35,8	37,2
P2	28,5	26	30,5	23,5	27	28,3
P3	44,6	45,4	46,6	39,1	43	44,1
P4	31,6	32,8	37,1	34,3	33	32
P5	53,4	50,6	50,8	46,2	47,6	51,3

	Mean	SD	N	95% confidence level
B1	42,68333333	9,059309684	5	7,94068914
B2	36,22666667	11,13369949	5	9,758938564
B3	41,73333333	9,192288122	5	8,057247738
B4	38,14666667	8,334545199	5	7,305416733

	Dist eye-table (cm)	Conspicuity angle (deg)	95% Confidence level (deg)
B1	57	36,82698549	6,851190405
B2	57	32,43822579	8,738387541
B3	57	36,21023586	6,990930696
B4	57	33,79201171	6,471462629

Simulator test

The next pages presents additional information regarding the simulator test conducted at IFE in Halden. Including an information letter to participants, presentation of the team members, scenario description, semi-structured interviewguide, and evaluation scheme.

An informative letter sent out to partipants in the simulator test. The framework of the test was explained, as well as other practical information and the team conducting the test iwas ntroduced.

Informasjonsbrev til deltakere

Takk for at du vil delta på brukertesten i Halden, 21 eller 22 april 2016. Studiet vil foregå i IFEs ATM-Lab (Os Allé 7, 1777 Halden) og datainnsamlingen varer ca. 3 timer pr. deltaker. I løpet av den tiden vil vi:

1. Forklare studiets hensikt og gjennomføring.
2. Presentere simulatormiljøet og samle inn bakgrunnsinformasjon (alder, utdanning etc.).
3. Kjøre tre korte testscenarier på vår ATM-simulator (med pseudopilot) der du som flygeleder prøver ut nye grafiske designløsninger. Scenariene etterfølges av et debriefingintervju der du gir tilbakemelding på våre designforslag. Formålet med den nyutviklede grafikken er å tilby flygeledere økt informasjon for å motvirke Controlled Flight Into Terrain (CFIT).
4. Kjøre to korte testscenarier med debriefingintervju der du vurderer en ny måte å presentere værinformasjon på (studentarbeid).

Dine personopplysninger behandles konfidensielt og alle innsamlede data (f.eks. spørreskjema, intervjunotater og simulatorlogger) lagres og rapporteres slik at anonymiteten til deltakerne blir ivaretatt. Individuelle prestasjoner i testscenariene er forskningsmessig uinteressante for oss ettersom studiene i ATM-Lab fokuserer på generelle problemstillinger som grensesnittdesign, arbeidsprosesser og oppgavekompleksitet. Vi vil ikke gjøre videoopptak eller fotografere under datainnsamlingen uten at det er gjort eksplisitte skriftlige avtaler om dette.

Hver deltaker gjennomgår dette programmet individuelt uten at kolleger, observatører eller andre er tilstede. IFE vil være representert med flere personer for å gjennomføre brukertesten, og på side 3 finner du korte beskrivelser av dem og hvilke roller de har under datainnsamlingen.

Vi ønsker at hver deltaker velger ut den av sesjonene som passer best, koordinerer dette seg imellom og gir beskjed til Marit Howell ved å benytte vedlagt skjema. Hun videreformidler dette til IFE.

Sesjoner:

S1 – torsdag 21.4., kl. 08.45 – 12.15

S2 – torsdag 21.4., kl. 12.45 – 16.15

S3 – fredag 22.4., kl. 08.45 – 12.15

S4 – fredag 22.4., kl. 12.45 – 16.15

Fra ca. kl. 12 – 13 serveres lunsj for deltagere i IFE sine lokaler. Ankomst for de av dere som deltar i sesjon S2 og S4 og som ønsker lunsj er senest kl. 12, og kl. 12.45 for de som eventuelt ikke ønsker lunsj. Husk å gi tilbakemelding om dere ønsker lunsj eller ikke i vedlagt skjema.

Ved ankomst med bil er adressen **Os Alle 7, Halden**. Parkering er på merket gjesteparkering bak bygget; se vedlagt kart side 2. Dere trenger ikke parkeringsoblat; dette er tatt hånd om.

Ved ankomst med tog vil adressen fortsatt være **Os Alle 7, Halden**; ved normal gange bruker dere ca. 10 minutter; med taxi ca. 5 minutter. Bestill taxi i god tid før ankomst på tlf. 69 21 32 00. Relevante ankomst-tider for toget i Halden er kl. 08.45, 11.45 og 12.45. Ønsker dere å ta tog ber vi at dere opplyser om dette i vedlagt skjema, slik at vi kan tilpasse sesjonene.

Kontaktperson ved ankomst IFE er Hans Olav Randem ved mo[redacted]

Dersom du har spørsmål kan du kontakte Christian Raspotnig [redacted], Alf Ove Braseth [redacted]) eller Gyrd Skråning ([redacted]

Velkommen til Halden!

Kort biografi av deltakere fra IFE

Alf Ove Braseth har bred bakgrunn innenfor design av skjermbasert grafikk for tekniske systemer. Han har de senere år utviklet grafikk for å operere prosesser innenfor: petroleum, nukleært, bank/sikkerhet og nå innenfor radargrafikk og luftfart. Under brukertesten vil Alf Ove bistå ved behov under intervju og med forklaringer av skjermbasert grafikk.

Gyrd Skråning har arbeidet som forsker ved IFE siden 1996. Mesteparten av denne tiden har han jobbet med testing og evaluering av kontrollrom innen prosesskontroll, men han har også noen års erfaring fra flygeledelse - blant annet som metodeansvarlig for evalueringsstudier hos Eurocontrol. Gyrd har psykologibakgrunn og vil fungere som testleder under datainnsamlingen.

Christian Raspotnig har jobbet som LTT-fullmektig ved Rygge kontrolltårn og AFIS-fullmektig ved Fagernes tårn i perioden 1997-2005. Han har tatt utdanning innen - og ved IFE jobbet med - sikkerhet i operative ATM systemer og IKT-systemer. Under datainnsamling vil Christian fungere som pseudo-pilot i test-scenariene og være med som intervjuer under debriefing-intervjuene.

John Eidar Simensen har bakgrunn og erfaring fra sikkerhetskritiske systemer innen luftfart, militære systemer, jernbane og fra det nukleære. Han har også flere år operativ tjeneste i luftforsvaret og vil under datainnsamling fungere som pseudo-pilot i test-scenariene og være med som sekretær under debriefing-intervjuene.

Hans Olav Randem er utdannet sivilingeniør innen data, og jobber med programmering ved IFE siden 1992. Under datainnsamlingen vil han ta imot deltakerne, og være tilgjengelig i tilfelle tekniske problemer.

Stine Marie Hjetland studerer Industriell Design på NTNU i Trondheim. I samarbeid med IFE skriver hun nå masteroppgave om oppsett og presentasjon av værinformasjon for flygeledere. Stine vil lede test-scenariene og tilhørende debriefing-intervju knyttet til hennes masteroppgave (se punkt 4, side 1).

Cb-scenario

The two scenarios is described in text. This description was not sent to the participants.

<u>Scenarier, Cb-skyer</u>

Stine Marie Hjetland

Hvert scenario varer i 10 min.

Scenario 1:

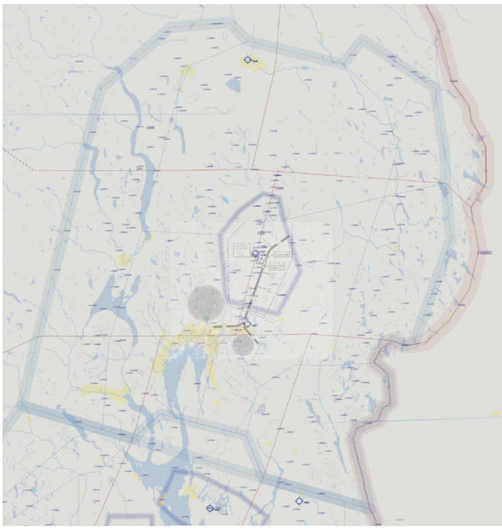
1. Scenariet kjøres i 1 min uten CB-grafikk. 00:00 – 01:00
2. Etter 1 min oppstår den høyre Cb-skyen (den minste). 01:00 – 04:00
3. 3 min etter punkt 2 oppstår også den venstre Cb-skyen. Skyene opptrer sammen på kartet med moderat arbeidsmengde (slik at det er overkommelig å svare på spørsmål underveis) i 4 min. 04:00 – 08:00
4. Etter totalt 8 min øker arbeidsmengden (denne overgangen kan starte gradvis litt tidligere) slik at testpersonen må konsentrere mer seg om oppgavene. 08:00 – 10:00

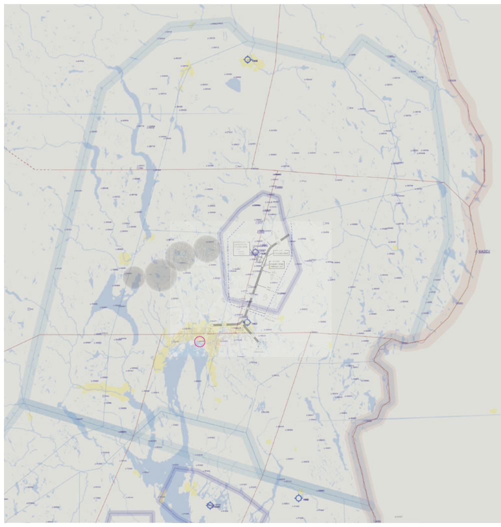
Scenario 2:

1. Scenariet kjører i 1 min uten Cb-grafikk. 00:00 – 01:00
2. Etter 1 min oppstår de to Cb-skyene til venstre i rekken. 01:00 – 02:00
3. Etter enda 1 min oppstår resten skyene og danner den helhetlige rekken av Cb-skyer. 02:00 – 10:00
4. I løpet av de siste 2 minuttene 08:00 – 10:00 øker arbeidsmengden gradvis.

Når en CB-sky oppstår, hvis mulig, skal den gradvis komme til syne fra «0 – 100» på ca. 5 sekunder. Dette kan evt. Også koordineres slik at pilotene melder inn rundt samme tidspunkt at det ser mulige Cb-skyer i området.

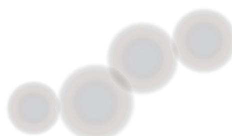
Grafiske elementer: Sirklene er egentlig helt svarte, men med en radial gradient som er satt til 20% opacity i innerste ring og 10% opacity i ytterste ring – med myke overganger mellom.





Sky-scenario 1

Sky-scenario 2



Semi-structured interview

Main goal of the interview: Uncover crucial design mistakes and overall usability

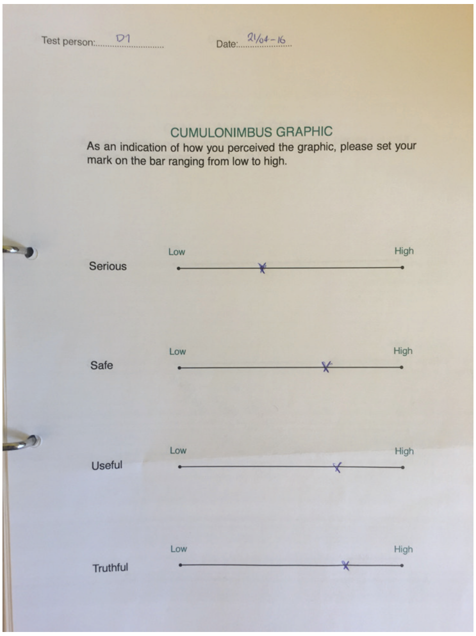
During the test

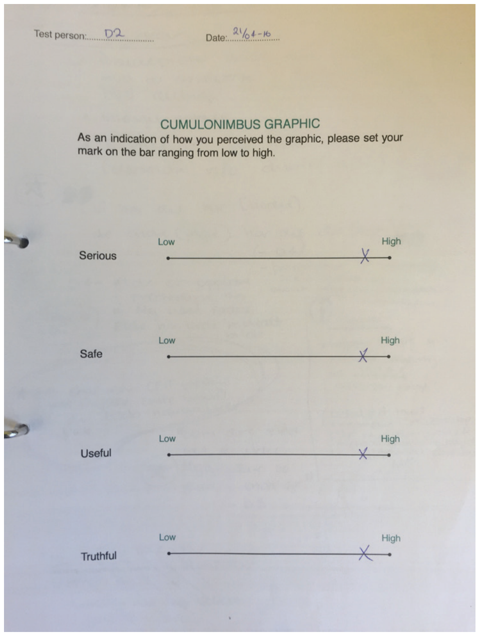
1. Inform the test person that I am not testing her, but rather the possible solution implemented in the simulator. The solution I am testing will not be presented before it is uncovered in the simulator during the test scenario.
2. Ask the test person to talk while working. Telling me: What she thinks, how she plans her work ect.
3. “How do you interpret/perceive the object?” – when the object is introduced in the simulator.
4. “What do you think of the object?” What do you read out of it?
5. After observing how the ATC works with the object: “Do you include this object in your work?”
6. “How will you include it or take it into account?”
7. “How close to the icon do you mean it is safe to fly?”

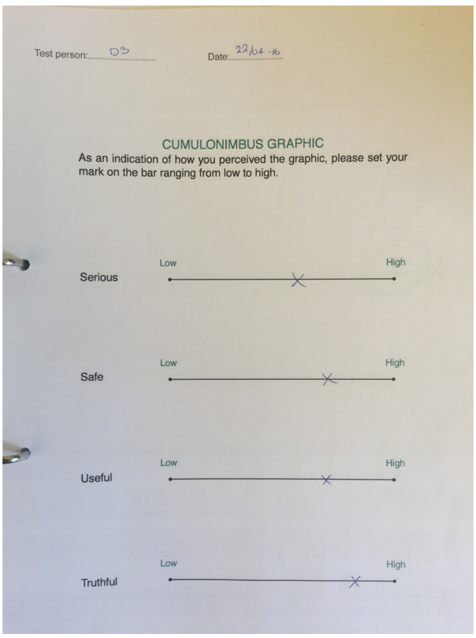
After the test

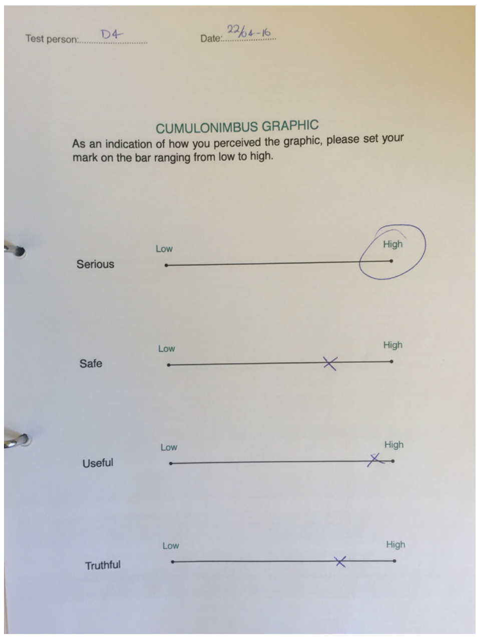
1. What do you think about the solution?
2. Would you use it?
3. (Hand the test person a sheet with bars on it) “Please place a mark on the bar from low to high, indicating how you perceived the graphic”:
    a. Serious
    b. Safe
    c. Useful
    d. Truthful

Evaluation-scheme: Results









Evaluation of the result based on the key findings found relevant for further development (based on insight and analyzis) and key findings found in theory studies. Each finding is marked in green, yellow or red showing if the findings has been answered, taken into account or not answered/missing from the solution. Answered - taken into account - Not Answered

Key Findings found relevant for further development	Short Comment
• Cb seldom need quick response from the ATCO. It is more of an awareness, and reminder. One less thing to remember for the controller.	A graphical element on the radar screen, not too visible, or drawing too much attention.
• Aviation is a conservative field. Small changes are probably easier to implement and get approved, than radical changes, because of documented safety and useracceptance.	Keeping the solution based in the radar screen, like the exisiting solution. Thus the change are not too big. Further, th shape is not radically changed.
• ATCOs need more accurate and honest weather information. Also regarding uncertainty.	This can always be better. However, it is taken into account in the devlopment and design process. And affected the design greatly with the diffuse lines and the “perfect” and unrealistic shape og a circle.
• The layout and display on the different workstations varies.	Keeping the shape as the biggest contrast might help the graphic maintain visible across workstations.
• Edda Systems GUI is very different from NATCON’s GUI. Both can be personally adjusted.	
• ATCOs are handling many points of contact. They need to prevent information overload.	Keeping the graphic similar to the exisitng, prevents it to from being new and confusing, demanding more attention. As transparancy helps maintain SA, this is included also as a factor to avoid information overload. A lot of information such as text is not included. The goal is to get enough information with only a look. However, this is a challenge in the world of ATCOs.

Key Findings from Theory Studies	Short Comment
• External aids may help increase the human memory	
• Shape and color communicates and indicates importance • Desaturated and dark colors are perceived as professional and serious respectively	The choice of color and shape is based on keeping the graphic serious, and important without overshadowing other more important information. Thus it is dark, and transparent.
• Low density can increase useful field of view (UFOV), and can help counteract tunnel vision.	
• Transparent layering helps containing SA.	The transparent graphic enable to see other objects underneath the Cb.
• Less eye-movement can help getting necessary input in a shorter time	By keeping the graphic on the Radar screen, the demand of eye-movement decreases as this is the screen right in front of them.
• • In order to not take unnecessary focus the Cb-graphic need easily processed information in coherence with the situation.	As technology develops this is something that can continue improving. However, keeping the graphic simple and intuitive, as tested in the simulator test, helps to ease processing the information.
• Avoid information overload by only providing the necessary information.	The balance between too little information and too much is a challenge.
• Quickly and easy distinguishable Cb-graphic from other graphical elements and the background.	Shape and color.

Key Findings from Theory Studies	Short Comment
• Cb-graphic should be designed to fit the graphical hierarchy in accordance to its level of importance.	The graphic should not draw too much attention, as it seldome emerge as a surprise. It is based on weather prediciton, thus this is something that is already provided in text to the ATCOs.
• Given that the quality of the information provided might vary it is important that the ATCO is aware of possible uncertainty in their data. Introducing this uncertainty through the graphic and in direct contact with the data eliminates the need of looking other places for confirmation.	Using diffuse lines and to layers in the graphic it immidatly communicate the possible uncertainty. Not needing to look elsewhere. This can be adjusted as proposed, based on future tech. developemnts.
• Needs a good mental model.	Dependent on other factors as well. But, as the conceptual solution is tested to be intuitive this might help establishing the mental model.
• Time perspective is important to establish SA level 3.	Not included, need tech. development. Not good enough today.