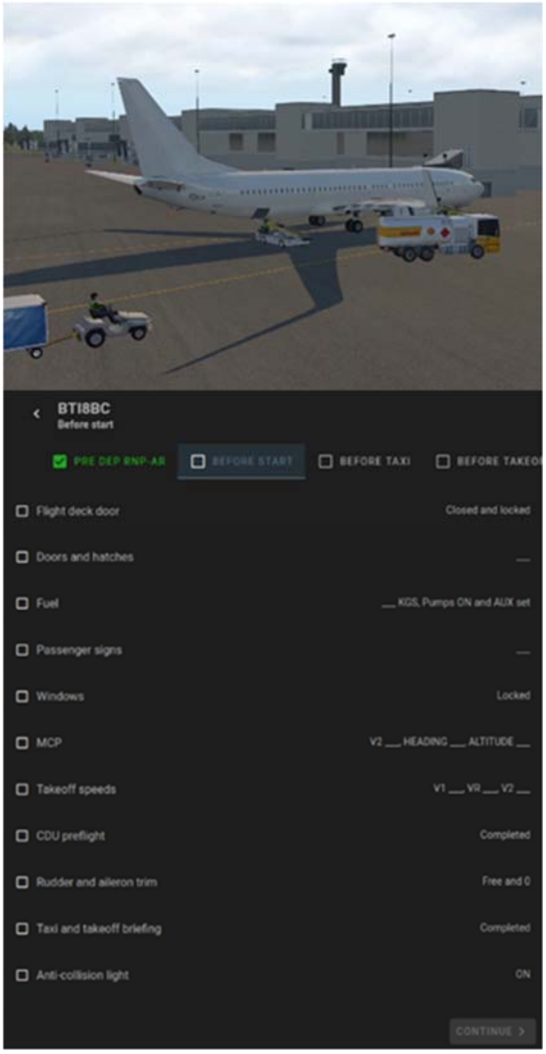
D-SAM Digital co-operation tools – Final report D-SAM project within the IRIS-programme

2021-11-17



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Content

1. Executive Summary

The airport operation of today is built upon a very complex chain of events that all contribute to every flight. All these events are important and almost all need to be completed before the flight crew can begin their process of preparing the aircraft for departure. If one of the essential contributors fail or become late in their process, the flight will be delayed which has a knock-on effect on the whole downstream network.

Many processes are affected by delays, but one example is that the unknown variance in departure times that is introduced due to delays, this affects the total airspace picture. The hypothesis behind the proposed D-SAM platform is built upon the exchange of information between the different contributors effecting the total airspace picture. The exchange of information is believed to enhance the situational awareness and predictability of every flight, ground operation, and air traffic controller using the D-SAM platform.

The legacy communication channels in contemporary commercial air transportation are becoming increasingly congested due the large number airspace users. This report is the result of a research and innovation project with the focus on making flows of information more transparent and accessible. The project was commissioned by the Swedish Transport Agency (Trafikverket) in collaboration with Swedavia AB, LFV (Luftfartsverket, and GEISTT AB as the provider of the research. This research and innovation effort has its roots in a report from Swedavia, the "ÖKA report" that was published in 2021 (Castor, Näs, Borgvall, Ekstrand, Linnér, Rappich, Wiklander, Elfström, & Ellerström, 2021). The ÖKA report investigated the challenges associated with the usability of RNP AR[1] (Required Navigation Performance Authorization Required) approaches into the Stockholm Arlanda Airport, Sweden. Findings in the report led to conclusions that there was a potential for improvement in the way communications was handled, which can lead to increases concerning the frequency with which RNP AR approaches can be allocated.

The communication gaps that were found in the "ÖKA report" became the foundation in the D-SAM project (Digitala Samarbetsverktyg – Digital Co-operation Tools translated to English). The D-SAM project was conducted in two stages:

[1] Required Navigation Performance Authorization Required (RNP-AR) https://skybrary.aero/bookshelf/books/4082.pdf

1. A review of scientific research literature and market practices together with comparisons of best practices used by airspace users.
2. An iterative concept development process with SME interviews (Subject Matter Expert).

The literature review consisted of information gathering from diverse scientific research sources with focus on communication systems technology development in both the aviation sector and other commercial sectors. The research analysis and literature review focused on the aviation sector and the development of new air traffic infrastructure, research focused on new air traffic concepts and research into the development of avionics.

The concept development process was conducted together with several SMEs from the aviation industry, both air traffic control experts with different areas of responsibility: Terminal Controller, Tower Controller, commercial pilot, and SME within the A-CDM concept[2] (Airport collaborative decision making). The approach throughout the project has been to involve the end users from the beginning, and from their expertise build upon the research and knowledge of the developers, using the methodology of IDEO's "Design Thinking" (Dorst, 2011).

In summary, this research has been conducted with the purpose to explore new communication channels, enabled by advancements in technology. One main idea of the research effort and the developed concept has been a stand-alone platform, outside of traditional, integrated legacy systems. The concept has been designed to share non-sensitive/unclassified information, specifically focused on the sharing of the sequences that an aircraft must complete, and the sharing of the information linked to that sequence. The concept was designed to complement the primary communication channels in use today, to enhance the situational awareness while lowering workload and complexity through the sharing of this sequence information.

The straightforward results from the concept development of the D-SAM platform, and the Smart Checklist demo application, can be accessed by watching the demo movie available at https://geistt.com/projects/dsam/[3]. The movie exemplifies two applications of the Smart Checklists application, but the D-SAM platform is believed to have a larger application space as it introduces a new type of data entry to SWIM and A-CDM systems, which provides

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[2] https://www.eurocontrol.int/concept/airport-collaborative-decision-making

3 The movie is publically available, and the password to the site can be achieved through contact with martin.castor@geistt.com, martin.insulander@geistt.com, jonathan.borgvall@geistt.com or anette.nas@swedavia.se.

an ability to “look into the process” in another way than various technical sensors and predictions can provide. The basic idea of D-SAM is the human operators such as pilot and ground handling crew that executes a work task, where checklists already are used, easily can check off them in an electronic tool such as D-SAM and thus provide process information that can be used in many applications of future air operations.

2. Sammanfattning

De traditionella kommunikationskanalerna som idag används inom kommersiell flygtrafikledning och inom kommersiell luftfart blir alltmer fulla då flygtrafiken (före COVID-pandemin) beräknades att tredubblas inom de närmaste 10 åren. Denna rapport har som primärt fokus att underlätta för dessa kommunikationskanaler och effektivisera informationsutbytet mellan flygtrafikledning och piloter. Studien har genomförts av GEISTT AB på uppdrag av det svenska Trafikverket och SWEDAVIA AB. Idén till forskningsprojektet uppkom under genomförandet av ÖKA-projektet vars rapport publicerades 2021 (Castor, Näs, Borgvall, Ekstrand, Linnér, Rappich, Wiklander, Elfström, & Ellerström, 2021). ÖKA-projektet undersökte olika orsaker som påverkar användandet av RNP AR inflygningsprocedurer (Required Navigation Performance Authorization Required), vad som kan göras för att öka användandefrekvensen och vilka utmaningar den nya inflygningstypen har inneburit. Ett av fynden i ÖKA-rapporten var förekomsten av bristfällig kommunikation mellan flygtrafikledare och flygtrafikledare med andra ansvarsområden, samt mellan piloter och flygtrafikledare. Dessa kommunikationsproblem och omständligheten av kommunikationsprocessen utgör grunden till detta forskningsprojekt.

De kommunikationssvårigheterna som identifierades i ÖKA-rapporten blev grunden till D-SAM-projektet (Digitala Samarbetsverktyg). D-SAM-projektet undersöker möjligheter till digitalisering av vissa typer av interaktion som redan existerar idag. Projektet genomfördes i två steg:

1. En litteraturstudie och omvärldsanalys
2. En iterativ konceptutveckling i samverkan med domänexperter (SME)

Litteraturstudien bestod av analys av diverse vetenskapliga källor med fokusområde kommunikationsteknik inom det kommersiella flyget men också inom andra industriområden. Omvärldsanalysen bestod till största del av analys av framtida luftrumsförändringar och procedurer med fokus på användandet av nya inflygningsmetoder och framtida flygtrafikledningssystem.

Den konceptuella utvecklingen genomfördes i direkt samverkan med domänexperter som flygtrafikledare och piloter. Flygtrafikledare med olika arbetsområden så som tornflygledare, terminalflygledare och flygledare med kompetens inom A-CDM (Airport Collaborative Decision Making) samt en kommersiell pilot bidrog i utvecklingsprocessen från start. Metodiken som har använts är baserad på IDEOs ”Design

Thinking” (Dorst, 2011) vilken utgår från att involvera slutanvändaren från början av designprocessen.

Som summering så har D-SAM-projektet utgått ifrån att utforska nya kommunikationssystem som finns aktiva idag men också forskning med fokus på framtida kommunikationssystem så som exempelvis SWIM, ADS-C med mera.

Det rättframt tillgängliga resultatet från konceptutvecklingen av D-SAM plattformen, och demoapplikationen med Smarta Checklistor, är tillgängliga via D-SAM demo filmen som finns tillgänglig via https://geistt.com/projects/dsam/. Filmen exemplifierar två tillämpningar av den Smarta Checklistor tillämpningen, men D-SAM konceptet har också vidare tillämpningar då det introducerar en ny typ av datainmatning till SWIM och A-CDM system, som ”ser in processen” på ett annat sätt än vad diverse tekniska sensorer och prediktioner kan ge. Grundidén i D-SAM är att den mänskliga operatör, exempelvis piloter och markpersonal, som genomför ett arbetsmoment, och där redan använder checklistor, lätt kan bocka av dem i ett elektroniskt system som D-SAM och då ge processinformation som kan användas på många olika sätt i framtida flygoperationer.

[4] Filmen är öppet tillgänglig och lösenord till websidan erhålls genom kontakt med martin.castor@geistt.com, martin.insulander@geistt.com, jonathan.borgvall@geistt.com eller anette.nas@swedavia.com.

3. Author Note

The project has been completed together with the following participants: Anette Näs[5], Björn Hansson[3], Lars Rappich[6], Jonas Söderlund[4], Erik Hellman[7], Martin Castor[5], Martin Insulander[5], Erik Strid[5], and Jonathan Borgvall[5].

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The authors would like to express the gratitude to the operative personnel at LFV and Swedavia as well as all others involved in the project, with special mentions to Lars, Jonas, and Björn.

[5] Swedavia AB
[6] LFV
[7] GEISTT AB

4. Introduction

The D-SAM project, from now on referred to as "the project", was commissioned by Swedavia. The partners of the project are Swedavia, LFV and GEISTT as a part of Trafikverkets Research and Innovation program in "the Air domain"-portfolio (Luftfartsportföljen). The project is linked to the strategic goals "Available and efficient airports in a sustainable society" (Tillgängliga och effektiva flygplatser i ett hållbart samhälle) and "Available and efficient airways in a sustainable society" (Tillgängliga och effektiva flygvägar i ett hållbart samhälle) as defined by the strategic research agenda of Trafikverket (Trafikverket, 2021).

The IRIS-program (Icke raka inflygningar till Stockholm Arlanda) has during the last years analysed and implemented several different programs to increase the number of curved RNP AR approaches to Arlanda airport (ESSA). Through the increased use of curved approaches, even during higher traffic intensity, considerable environmental and capacity related benefits can be achieved, which supports the longer-term goal of Arlanda airport being able to meet the environmental goals required for Arlanda's environmental permit. Curved RNP AR approaches have proved to be a successful tool in the challenge that the world is facing when it comes to environmental problems with regards to CO^2 emissions and other associated pollutions. Other benefits with RNP AR approaches are the lowered noise footprint and the reduced track miles required for the aircraft due to the ability to construct the approach based on a radius to fix instead of conventional point to point methods.

In the ÖKA report (Castor, Näs, Borgvall, Ekstrand, Linnér, Rappich, Wiklander, Elfström, & Ellerström, 2021), a study performed to identify the difficulties and challenges that are presented when using the RNP AR approaches. As a result of the report a communications process for efficient and effective decision making was lacking. The study showed that, for example, an air traffic controller in the terminal area would have to make several calls directly to confer about the decision that was being made. The complexity of this routine and the required time that it takes to complete the task hinders the controller from making timely and effective decisions. There have even been cases described as so limiting that the operator would not consider the option of an RNP AR approach because of the way the communications process is made.

The current report describes the outcome of a research and innovation project with the purpose of in-depth analysis of requirements and the feasibility (Proof of Concept) of a digital communications platform between flight crew and air traffic controllers with different areas of responsibility, to support the increased use of curved RNP AR approaches.

The tool that was conceptualized in this project complements todays existing tools for communication. D-SAM has been developed separately of existing systems as a means of direct communication, and a complement to the existing communications systems used today (i.e., voice communication via VHF) and was developed to increase safety and effectiveness for air traffic controllers and flight crew.

During the peak hours of Arlanda Airport (ESSA) the optimization goal of the Terminal Area Controllers (TMCs) are to land approximately 40 aircraft per hour. Which in turn equates to one landing every 90 seconds. The main part of the communication is made over traditional communication channels using voice communications via VHF-radio. During periods of peak traffic, the ability to accurately predict when a departing aircraft will enter the airspace of the TMC-controller decreases. Adding to the complexity for the controller to be able to assign RNP-AR approaches. The variance between ATOT and the ETOT, even if small, makes a big difference in the total airspace picture. The assumption is that, if the ability to predict when a departing aircraft would enter the airspace of the controller would increase, the ability to accurately determine if an arriving aircraft would be able to perform an RNP-approach would become easier.

Advancements in digital communications systems have made significant steps towards a modernization of communication technology in the aviation sector. These advancements with technologies such as CPDLC/ACARS/EPP have significantly increased the possibilities for non-verbal/voice communications and have greatly increased the possibility to share information. However, many of these implementations take a significant amount of time and due to lengthy certification processes in safety-critical systems.

D-SAM has been developed to focus on direct communication as well as sharing of sequences as a way of increasing situation awareness for its users without the lengthy certification processes and is intended to be used as a secondary support system and not a primary way of communication.

4.1. Rationale for project

The rationale for the project has been to increase the usability of RNP AR approaches into Stockholm Arlanda Airport which in turn has the effect of reducing environmental impact of the airport operations.

With the increased number of airspace users and the role of the air traffic controllers and pilots using the airspace become more complex, a need to relieve the traditional primary communication channels emerges. The use of a secondary system that increases the predictability and eases the congested voice communication channels opens up possibilities to increase the situational awareness of the system users. By having a system that is not sharing security sensitive data the lengthy certification process of an integrated system makes for shorter implementation timelines. That in turn by its benefits could decrease the total time delay on the ground and the knock-on effect downstream.

Another significant point in the project's rationale is the possible environmental benefits that the efficient use of RNP AR approaches and the lower carbon emissions as well as reduced noise footprint associated to the use of these types of curved approaches. The environmental benefits are also closely linked to Arlanda Airports environmental operational requirements.

4.2. Caveats and delimitations

The research projects delimitations are closely linked to the scope and extent of the project. Some of the caveats and delimitations are listed below:

- The primary focus on the communication between the flight crew and the air traffic controllers using the airspace.
- Only open, non-critical information will be shared.
- The showcase of the "smart-checklist" functionality as one of many proposed functionalities used to share information via the D-SAM platform.
- Only simple commands used in the application, such as "yes and no" type of questions or simple sharing of the state of the aircraft sequence.
- D-SAM is designed to act as a freestanding communications system that delivers only non-sensitive information and is not meant to be used as a primary communications channel.
- The outset that most aircraft at this time has integrated WIFI or other types of wireless connectivity such as 4G or 5G available at any time.

4.3. Literature review and related solutions

In this section a short presentation of the literature and the other sources of information is presented.

- The EMPHASIS Project by HONEYWELL[8] – A research project with the focus on how future communications channels will interoperate together with UAVs (Unmanned Aerial Vehicles) and all other airspace users using existing network connections such as 4G/5G. *This project has been an inspiration towards the use of non-conventional communication technologies for the air traffic sector.*
- SESAR JU project PJ32 DIGITS[9] – Demonstrating the use of 4D trajectory data transfers. *This project has been key to understanding the future of how airspace will be constructed and the increased need for more precise and timely communication together with time prediction.*
- SESAR JU project PJ17 SWIM-TI[10] – A project that describes the implementation of "System-Wide Information Management" (SWIM) a future technology service that can be subscribed to depending on the end user's needs. *An inspiration towards the future integration of services and a possible implementation strategy of a future operational D-SAM platform.*
- AeroMACS – Aeronautical Mobile Airport Communication System[11] is a standardized solution for the airport surface environment. *AeroMACS have contributed to the design process by using different applications accessible on the airport surface environment.*
- A-CDM lite[12] a SESAR JU project which implemented a "light-weight" version of the A-CDM concept on smaller airports, increasing situational awareness based on ADS-B data.

4.4. Assumptions of the design approach

Findings in the ÖKA-report was the basis to the underlying hypothesis or assumption behind the projects design approach. This assumption is essentially that the D-SAM system, through integration of information and the ability to share that through a common platform with simple

[8] https://aerospace.honeywell.com/us/en/pages/emphasis-project
[9] https://www.sesarju.eu/sites/default/files/documents/projects/Airtel_PJ.31%20_Doc_Web.pdf
[10] https://cordis.europa.eu/project/id/731826
[11] https://www.icao.int/SAM/Documents/2018-SAMIG22/AeroMACS%20Presentation%20-%2022November2018_Final.pdf
[12] https://www.sesarju.eu/sites/default/files/documents/sid/2019/papers/SIDs_2019_paper_76.pdf

interactions, would be useful to complement the todays overloaded communication channels.

Through integration and the ability to share information through a common platform, which benefits from simple interactions that is already standardized practises today would increase the predictability of when a certain process would be completed. This in turn would increase the ability to make correct decisions by having more accurate information at hand. By using D-SAM as a separate communications platform outside of the traditionally integrated channels, much like the EFBs used today by flight crew, would decrease the time required and the associated costs to implement changes in the D-SAM platform. It is the assumption that the sharing of processes from the different actors in the airport environment would significantly increase the ability to predict in which state an aircraft is in at a specific time. Increasing the predictability for the air traffic controllers to make timely and effective decisions to increase throughput and efficiency both in the airport environment but also in their respective airspace sector.

Today's airport operation contains a very complex chain of events that all contribute to every flight. All these events are important and almost all need to be completed before the flight crew can begin their process of preparing the aircraft for departure. If one of the essential contributors fail or become late in their process the flight will be delayed which has a knock-on effect on the whole downstream network. The hypothesis behind the D-SAM platform is built upon the exchange of information between these different contributors to enhance the situational awareness and predictability of every flight, ground operation and air traffic controller using the platform.

5. Method

This section describes the method used to develop the D-SAM concept. It also describes the participants that were selected and the interviews that were made.

5.1. Participants

The participants used in the project were recruited through direct contact with respective organizations representatives, LFV and Swedavia.

The participants or subject matter experts chosen for this project have backgrounds from the air traffic control sector. The participants represent air traffic controllers with extensive experience in Tower Control, Terminal Control as well as an SME in A-CDM[13]. One commercial pilot was also involved in the project with experience from both short- and long-haul worldwide operations.

The participants represent a group of 3 SMEs[14] in the air traffic control sector with a high level of experience as well as one experienced commercial pilot. Because of their experience they represent a wide range of expertise in their separate domain. The selection does not represent a less experienced Air Traffic Controller or pilot which might affect the outcome of the project. However, considering the extensive experience from different parts of the world as well as the knowledge from the airspace surrounding Arlanda Airport, the participating group should be representative of a larger group of Air Traffic Controllers. The extent of the project and its budget made these participants representative of a collective view.

5.2. Data collection and research design

Figure 1 describes of the collection of the data that has driven the design process.

Figure 1 Research design outline.

[13] Airport Collaborative Decision Making (A-CDM)
[14] Subject Matter Experts (SME)

5.2.1. Interviews

The interviews were conducted based on the IDEOs Design Thinking[15] principles, where the process of the design of the concept is a collaborative and iterative effort. Through this iterative design process, the concept gets direct input at an early design stage by the end user. Therefore, the design process advances at a faster pace and inputs can be implemented by the design team at an earlier stage as well as tested rapidly.

The interviews were conducted through online video conferences due to the physical distance measures in force during the COVID19-pandemic. During the concept development, the participants were presented with the D-SAM concept in varying stages of completion. Figure 2 exemplifies an early flow chart used to map the relevant actors and processes during one of the first workshops. The participants were allowed to directly affect the design process through discussions that were both open and led by the design team.

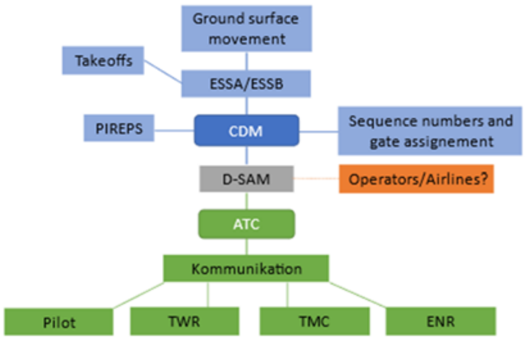

Figure 2 An example of an early concept flow-chart shown to the participants.

The structure of the interviews was following an outline consisting of the following:

- An introduction and a review of what had been said in the earlier meetings.
- A short presentation from the design team of the progress made since the last meeting as a part of the iterative design process.
- An open design discussion where the participants and the design team could voice their opinions, requests and design inputs.
- All the meetings were recorded and kept for reference for the conceptual development.
- Goals were set for the next workshop.

[15] https://designthinking.ideo.com/

5.2.2. Task analysis with FRAM

The complexity of the communications process and the sequencing of events of the turnaround process was chosen as the design context. This turnaround process covers from when an aircraft arrives to its stand and starts deboarding passengers until it closes its doors and is ready for pushback for another flight.

This process was analysed in depth using a task analysis method called FRAM[16], i.e., Functional Resonance Analysis Method (Hollnagel, 2102), emerging from cognitive systems engineering (Holnagel & Woods, 2005), and which is a main analysis method of resilience engineering (Hollnagel, Woods, & Levenson, 2006). The method is used to identify variability in a system and how these variabilities can create a resonance. Figure 3 shows an example from the conducted FRAM analysis. The method is used to find these links and come with recommendations of how to dampen the resonance. The details of the conducted FRAM analysis are provided in Appendix A.

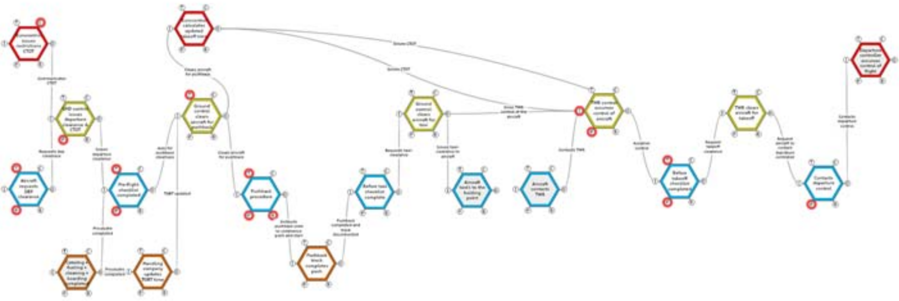

Figure 3 FRAM analysis of the sequences required until take-off.

The FRAM analysis shows how the complex interactions between the different actors all are dependent on each other. Which in turn emphasizes the internal and external factors and processes that needs to be considered before an aircraft takes off.

If these sequences can become more efficient and easily monitored by all the actors involved in the process, delays and uncertainty could be decreased and making decision making easier for all actors.

The project budget allowed only for a part of the whole communications process to be analysed, a deeper more substantial analysis is required to understand the complete process and how to improve upon these using the D-SAM platform.

[16] https://functionalresonance.com/brief-introduction-to-fram/

6. Results

D-SAM Smart checklists functionality

As a result from the task analysis and the design process, a list was compiled with all the contributors involved in the different stages flight, as indicated in Figure 4 below.

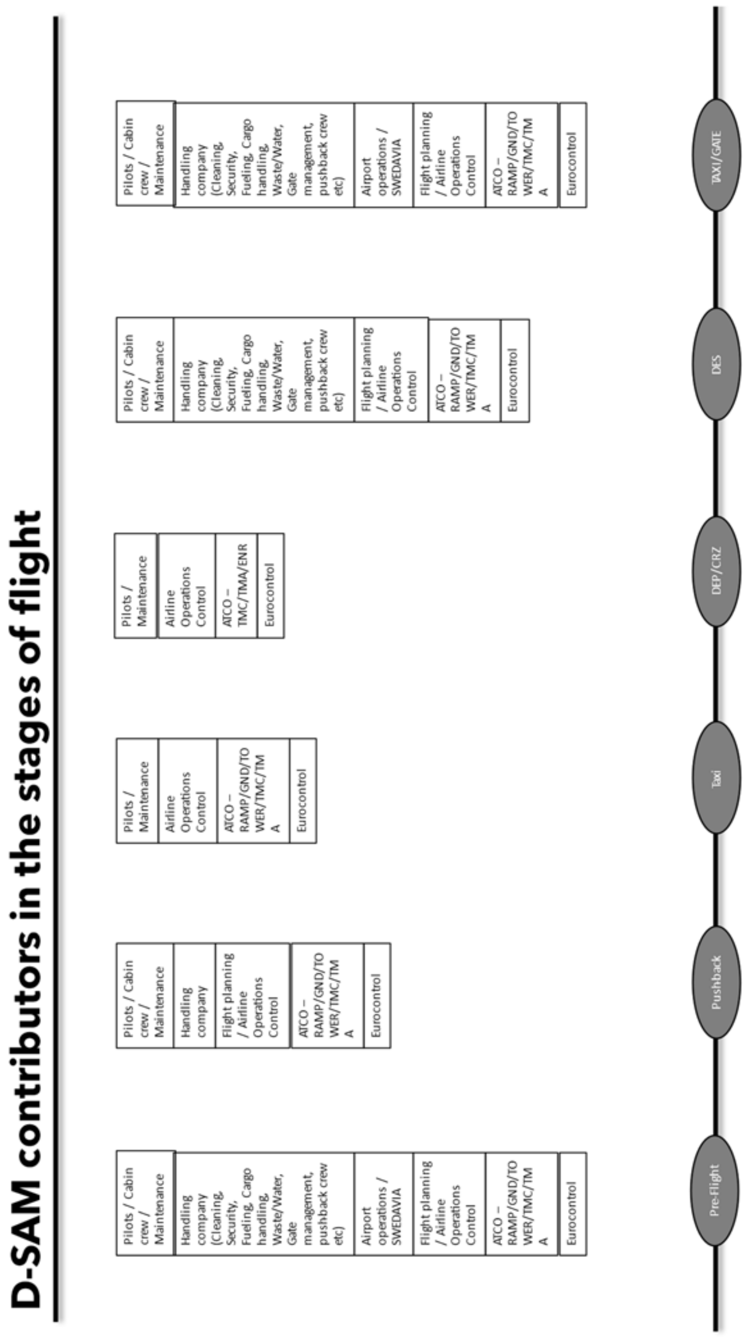

Figure 4 D-SAM contributors in various stages of flight.

As it became clear that the interdependencies and the complexity of the communication process between the different actors created a bottleneck for efficiency, see Figure 5, the Smart Checklists application was created to collect information using a process that is mandatory for any flight crew i.e., checklists. The use of checklists for flight crew is an essential safety net that is mandatory to use on any flight and ensure that necessary steps are completed, in sequence, to maintain a safe operating environment. The use of checklists is an integral part of the flight crews normal working tools used in order to identify processes that are either completed or not completed. The checklist used during a normal flight are directly corresponding to the phase of flight that the aircraft is in.

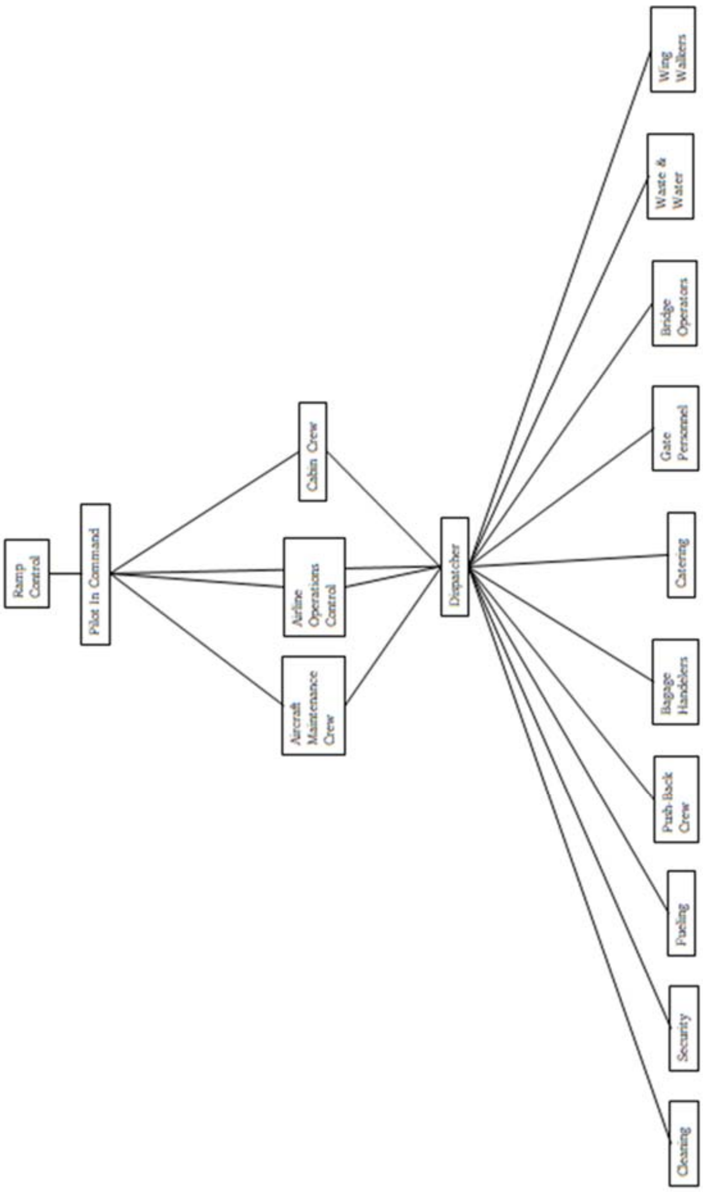

Figure 5 Communication process bottle neck.

The Smart Checklists application was constructed to share the sequence information with different actors using the D-SAM platform. One of the main receivers that were focused on in this project were ATC-controllers[17] with the area of responsibility as: Ramp Controllers, Tower Controllers, Departure Controllers and Terminal Area Controllers which reflects the participants areas of expertise and therefore had the most insight into these areas. By focusing on these receivers of the information provided by flight crew using the Smart Checklists, a clear example for usability arose.

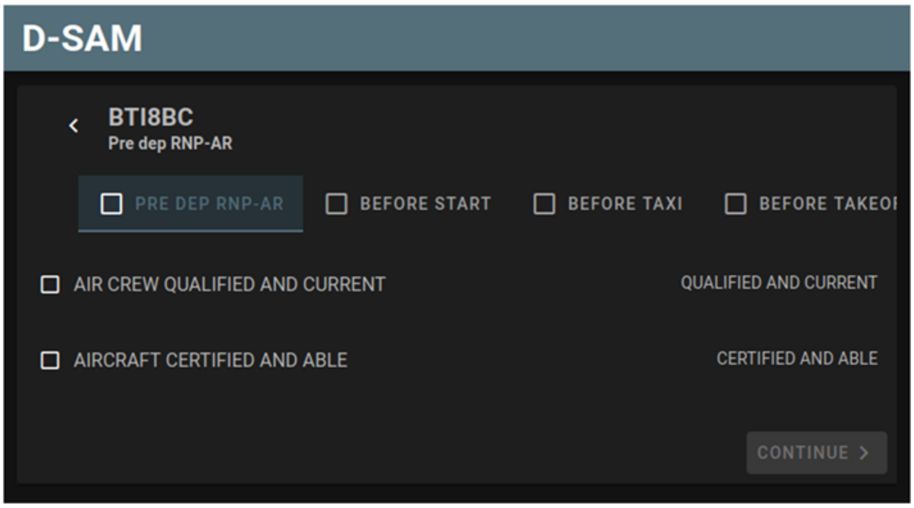

Figure 6 D-SAM checklist for RNP unfilled.

The Smart Checklist were designed in such a way that it resembles the use of a normal paper-type checklist that is used today by flight crew and converting it to a digital format, Figure 6 to Figure 12 shows screenshots from different stages of checklist completion. As evident from these screenshots a basic principle of the D-SAM platform is that the actor executing his or her part of the sequence uses only simple commands/interactions, such as answering "yes and no" type of questions or checking a completed processes step rapidly form very useful and shareable information concerning the state of the aircraft sequence. The user interface or the Human Machine Interface (HMI), of the D-SAM checklist is very simple and harmonises with how pilots work today, i.e., going through different checklists during different stages of the flight. The additional load on the pilot of checking off the boxes in the checklist should be minimal.

Making the user interface simple and highly similar to current ways of working, the need for retraining will be reduced.

[17] Air Traffic Controller (ATC)

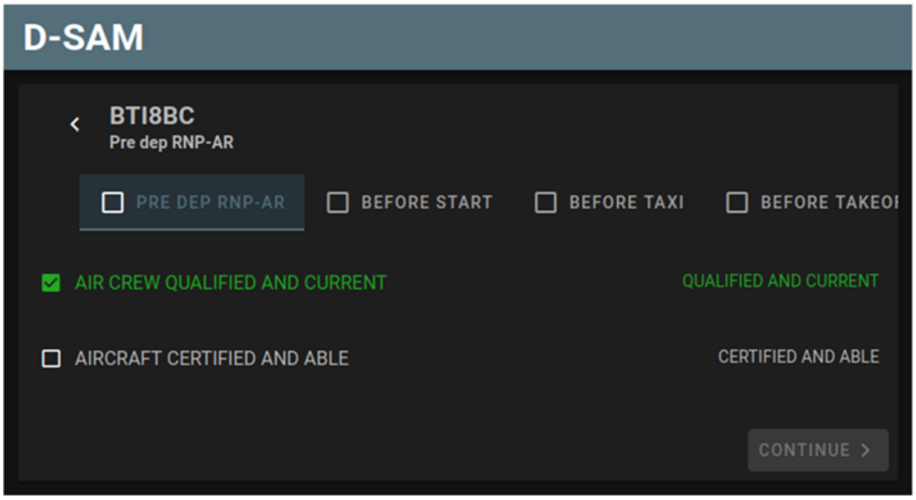

Figure 7 D-SAM checklist for RNP partially filled.

As one item is completed its related colour changes from white to green to indicate its completion.

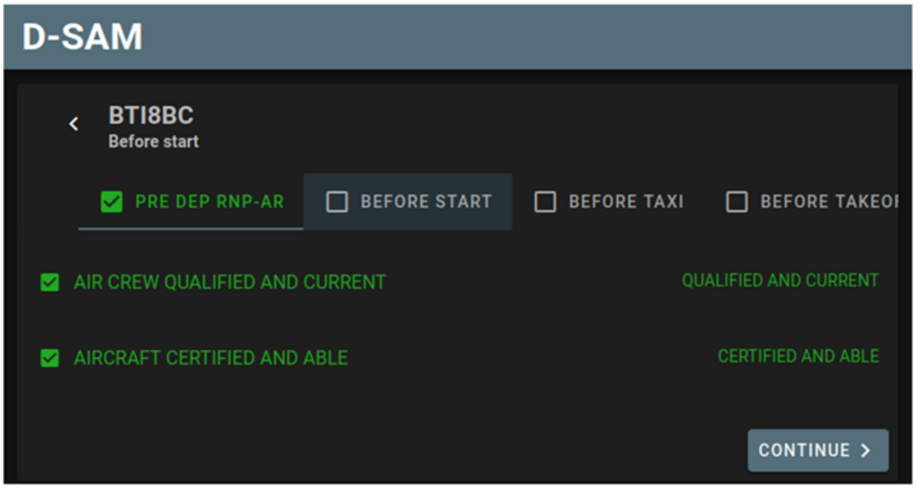

Figure 8 D-SAM RNP checklist completed.

When all the items of the checklist are completed the checklist section shows green and prompts the user of the next available checklist in sequence. Once the whole checklist has been completed, the information of the change of sequence is sent to the Air Traffic Controller with the responsibility of the aircraft at that moment in time.

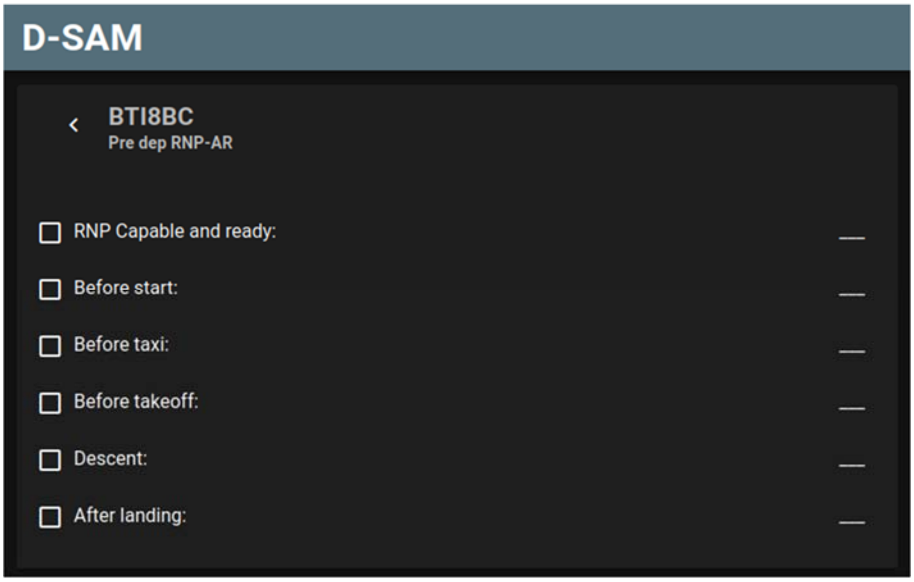

Figure 9 Air Traffic Controller sequence view unfilled.

The Air Traffic Controllers view of the Smart Checklist application is based on the aircraft selected and shows the related stage of flight that the aircraft is in. As the sequence of the aircraft changes, the status of the aircraft changes for the Air Traffic Controller.

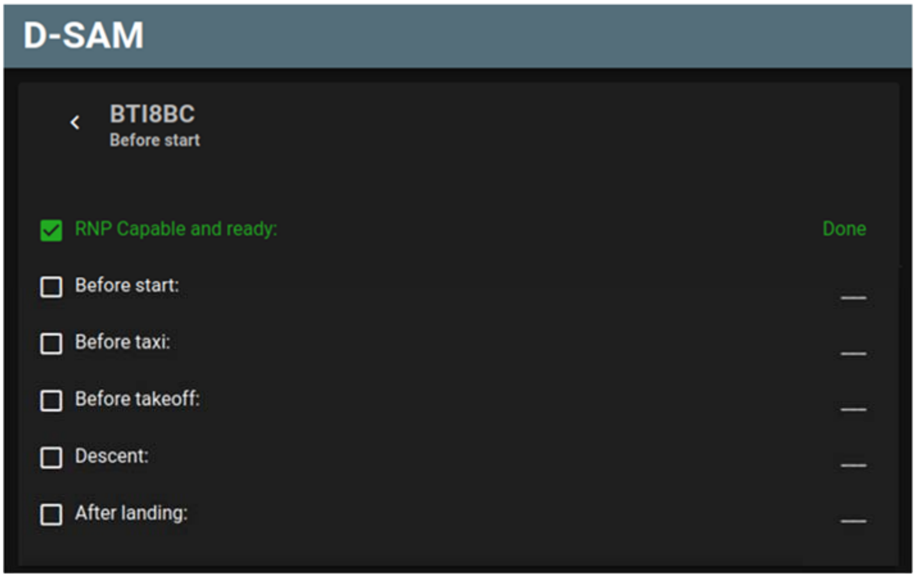

Figure 10 Air Traffic Controller sequence view partially filled.

As the air traffic controller can see the related change of the aircraft, the controller can make more effective and timely decisions regarding the aircraft and its capabilities. Such as in the example above where a new type of checklist, a pre-departure checklist that takes into regard the ability of the aircraft and its crew to perform RNP-AR approaches is available. This checklist is supposed to increase the readiness of the flight crew for a possible RNP-AR procedure as well as giving the Air

Traffic Controller the required information that the aircraft is able to perform the approach type.

For example, as the “Before start” checklist is completed, the sequence view of the ramp controller changes and is given the information that the aircraft is ready for pushback. Making the information readily available to the controller provides the user with the option to clear the area for the aircraft that is required during pushback. As the time available for an aircraft issued a CTOT, a window of – 5/+10 minutes is given for the time to complete the pushback. During the interviews with the participants, instances of when an aircraft has been within its time-limit to push-back but delayed from the target off block time (TOBT[18]) was described. The instances when the actual off block time (AOBT[19]) differed from the TOBT but was within the CTOT pushback time created a time span of 10 minutes when the TMA-controller could not estimate the actual take off time (ATOT[20]). Uncertainty exists when the TMA-controller cannot accurately estimate the actual time the aircraft was about to enter the airspace. This in turn hindered the use of RNP-AR approaches of incoming aircraft since the TMA-controller could not ensure that the required airspace of the incoming aircraft would remain free of other traffic.

The D-SAM sequence view is predicted to assist the various Air Traffic Controllers in estimating when an aircraft would be entering their area of responsibility. Making the required decisions associated with RNP-AR approaches timely and effective. This has the possibility to have significant benefits for the actual airport throughput, but also environmental gains as a result of the increased use of RNP-AR approaches.

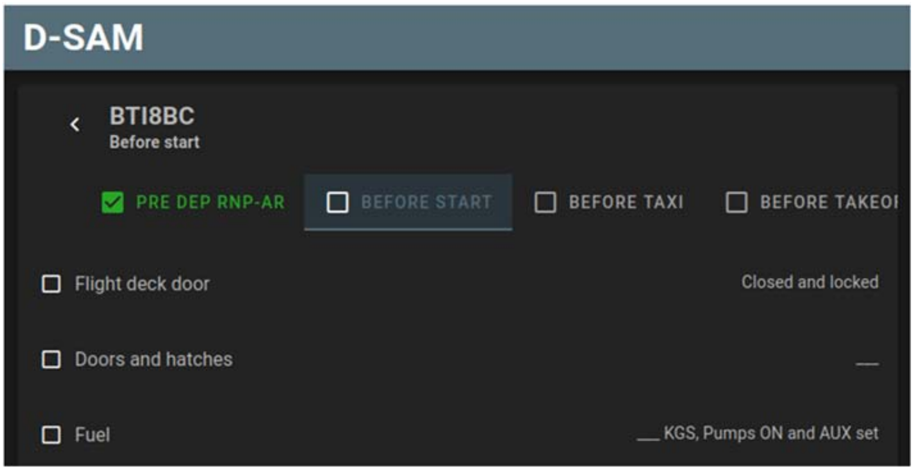

Figure 11 D-SAM checklist with integrated information sharing from outside contributors.

[18] https://ansperformance.eu/acronym/tobt/
[19] https://ansperformance.eu/methodology/unimpeded-taxi-out-time/
[20] https://ansperformance.eu/methodology/unimpeded-taxi-out-time/

In checklists where actors such as the fuel truck operator and ground handlers, who are loading and unloading the aircraft, are relevant these actors could use the D-SAM platform to share their sequence progress, and once the process is completed the information, e.g., amount of fuel loaded, is fed to the D-SAM platform and becomes an input in the flight crew's checklist.

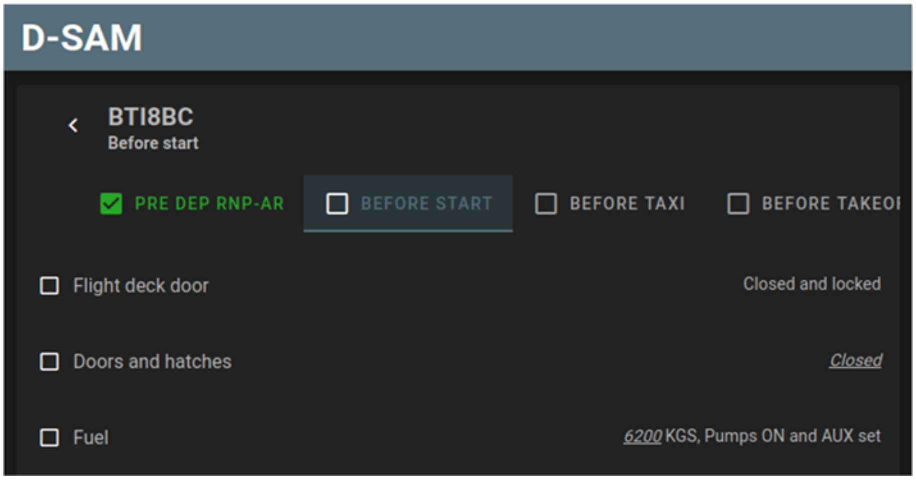

Figure 12 Contributor's sequence completed.

The process information provides an ability for the flight crew to know in which state the different actors are in. This directly effects the ability of the flight crew to complete their required tasks. The information shared could also be used to complete mandatory processes of crosschecking, for example the receipt provided by the Fueller could be sent digitally instead of printed as is the case today. The ability to shorten the turnaround time for airlines would also mean significant savings as the allocated time to use the gate would decrease.

Because of the scope and size of the project, only a certain amount of the communication process was able to be deeply analysed, but the findings from the project indicate that the overall complexity and the intricacies of the communication process, even before the flight has begun, is shown as a result of this project. The many actors, which all are essential in the operation of the aircraft and in its ability to complete its flight within the time frame given, makes the operation very complex and prone to errors, that previously have been difficult to detect. Because of how the D-SAM platform has been designed with its easy-to-use interface these complex communications processes have become more accessible. The participating SMEs understood the demonstrated functionality well and thought that it would enhance their situational awareness, making their decision making more effective. The actors of the turnaround process should therefore be able to make more effective decisions as they get a better understanding and predictability to understand the state of the sequence the aircraft is in.

After the video concept had been shown to the participants (SMEs), they were asked to fill out a survey where they were able to leave open comments about the concept and how they perceived the effect that it would have on their daily work. The scale that was used was a subjective scale from 1-5 (1=low agreement to high agreement) of how effective the participant experienced the effect of how the D-SAM platform would be. The survey was constructed with 2 questions regarding separate statements:

1. I think that the D-SAM concept would be able to provide an enhanced effect because the processes become clearer in an easily understandable way, to get a better understanding of the situation of the aircraft in question.
2. I think that the D-SAM concept is valuable enough to motivate a following “D-SAM 2” project.

The average result of the questions was:

1. 4 out of 5
2. 4.33 out of 5

The high results of the survey reflect upon that the project was successful in finding good examples of bottle necks where the information flow was restricted due to the technology used today. This in turn gives a good ground for another project taking the platform further.

The concept prototype that was developed is presented in a demo movie, available at https://geistt.com/projects/dsam/. In the movie the Smart Checklist application is shown in a simulated, but relevant context.

Due to the limited scope of the project, the primary focus has been on the turn around process of the aircraft, and the different states associated to it. By including the different contributors involved in the turnaround process and by analysing their respective process within the time frame available. It is believed that if the whole communications process would be analysed in detail, even more effect could be achieved.

[21] Filmen är öppet tillgänglig och lösenord till websidan erhålls genom kontakt med martin.castor@geistt.com, martin.insulander@geistt.com, jonathan.borgvall@geistt.com eller anette.nas@swedavia.com.

7. Discussion

Using an iterative design thinking process together with SMEs from relevant parts of the aviation industry, such as Air Traffic Controllers with different backgrounds as well as pilots, a proof of concept could be developed. This prototype can be used as a steppingstone for a bigger project where a simulation of the implementation of this system could be analysed and tested to quantify the effects.

The results indicate that the D-SAM platform and the Smart Checklist application was well received by the SMEs, a summary of the results are found below:

- The predictability of the required time for the aircraft increased.
- The use of conventional voice communication to retrieve the information decreased.
- The overall situational awareness of the SMEs increased.
- Simplified use of checklists for flight crew – low possibility of not knowing which checklists that has or has not been completed.
- Should lead to lower congestion on the conventional communication channels, namely VHF radio communication.

As the predictability of the aircraft increase the expected results, that if the D-SAM platform was integrated over a network of airports, would be a significant decrease in accumulated delays. The increased predictability is also believed to assist the ATC controllers in making effective decisions in controlling the aircraft.

To be able to test the new hypothesis concerning what it would resemble if there was a high implementation of the D-SAM platform across a network of airports and users the need for a secondary project emerges. In this project simulation would be used to test the benefits of using D-SAM on a broader scale. The effects of the next project are believed to be:

- Significantly lower total airport delays across any network using D-SAM.
- Higher predictability for the Air Traffic Controllers using the platform.
- Reduced environmental impact as a result of higher predictability.
- It is also believed that other users would find the information provided interesting, such as: Airlines, Eurocontrol and other

airport operators for example. The ability to know in what sequence and step of that sequence any user of the D-SAM platform is in would be beneficial to increase efficiency.

8. Recommendations

Below follows a list of recommendations for the next steps for a continuation of the project:

- Deeply analyse all the phases of flight and all the actors involved using a similar methodology as in the current project.
- Use simulation to study the effects of D-SAM on a larger scale, including multiple airports and D-SAM users' ability to increase predictability and efficiency.
- Develop the Smart Checklist concept using active pilots and Air Traffic Controllers and evaluate it in a larger simulation.
- Study the possibility of integrating D-SAM as a part of a lightweight A-CDM concept for airports without the possibility of utilizing the full A-CDM concept i.e., smaller regional airports.
- Compare the cost/benefits of using the D-SAM platform compared to integrated systems as well as the pros and cons of the two.

The findings of the project indicate that there are several areas that need to be researched further. The reference group of SMEs have been increasingly interested in a continuation of the project and further research is advised. As the benefits of integrated information flows would increase not only situational awareness, but also building upon the environmental goals set by the Swedish Authorities and for the future generations using air travel.

9. References

Digital object identifiers (doi) have been included when available.

Castor, M., Näs, A., Borgvall, J., Ekstrand, H., Linnér, A., Rappich, L., Wiklander, N., Elfström, F., & Ellerström, A. (2021). *Slutrapport IRIS programmets förstudie ÖKA (Ökad användning av kurvade inflygningar)*. Available at: https://fudinfo.trafikverket.se/fudinfoexternwebb/pages/PublikationVisa.aspx?PublikationId=4551

Dorst, K. (2011). The core of 'design thinking' and its application. *Design Studies*, 32(6), 521–532. https://doi.org/https://doi.org/10.1016/j.destud.2011.07.006

Hollnagel, E., & Woods, D. D. (2005). *Joint cognitive systems: The foundations of cognitive systems engineering*. Taylor & Francis. doi: 10.1177/106480460701500208

Hollnagel, E., Woods, D. D., & Leveson, N. (2006). *Resilience Engineering: Concepts and Precepts*. Aldershot Hampshire, UK: Ashgate Publishing. doi: 10.1201/9781315605685

Hollnagel, E. (2012). *Functional Resonance Analysis Method: Modelling complex sociotechnical systems*. Ashgate.

Trafikverket (2021). *Trafikverkets Forsknings och Innovationsplan – För åren 2021-2026*. Available at: http://trafikverket.diva-portal.org/smash/get/diva2:1516095/FULLTEXT01.pdf

10. Appendix: FRAM analysis

See following pages for readability.

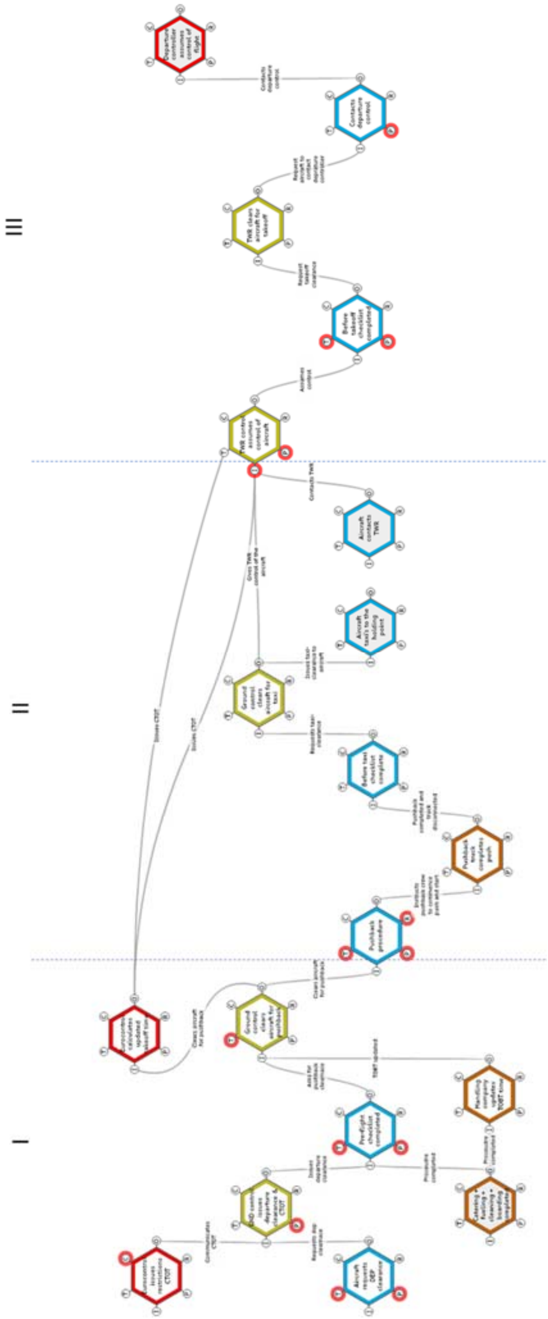

Figure 13. The full FRAM model of the turn-around process.

I

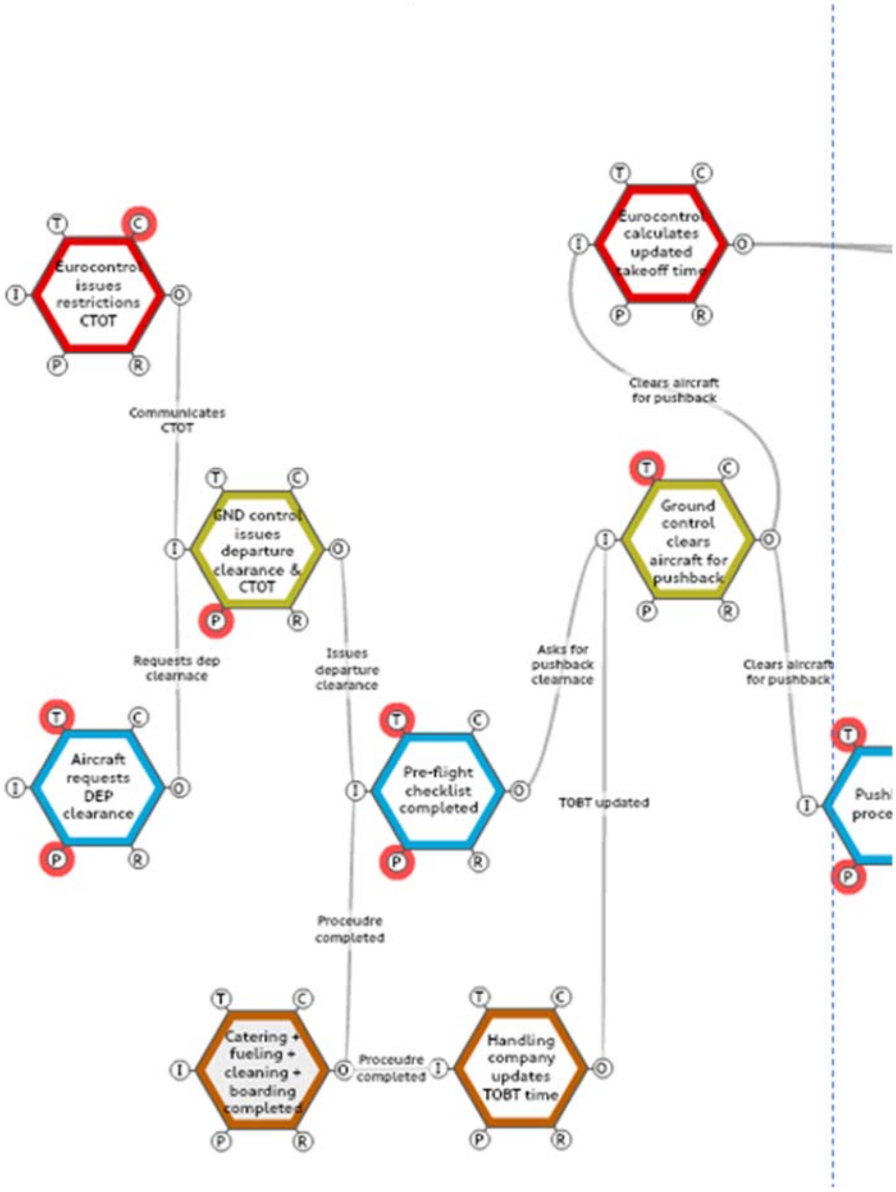

Figure 14. Left part of the FRAM model.

II

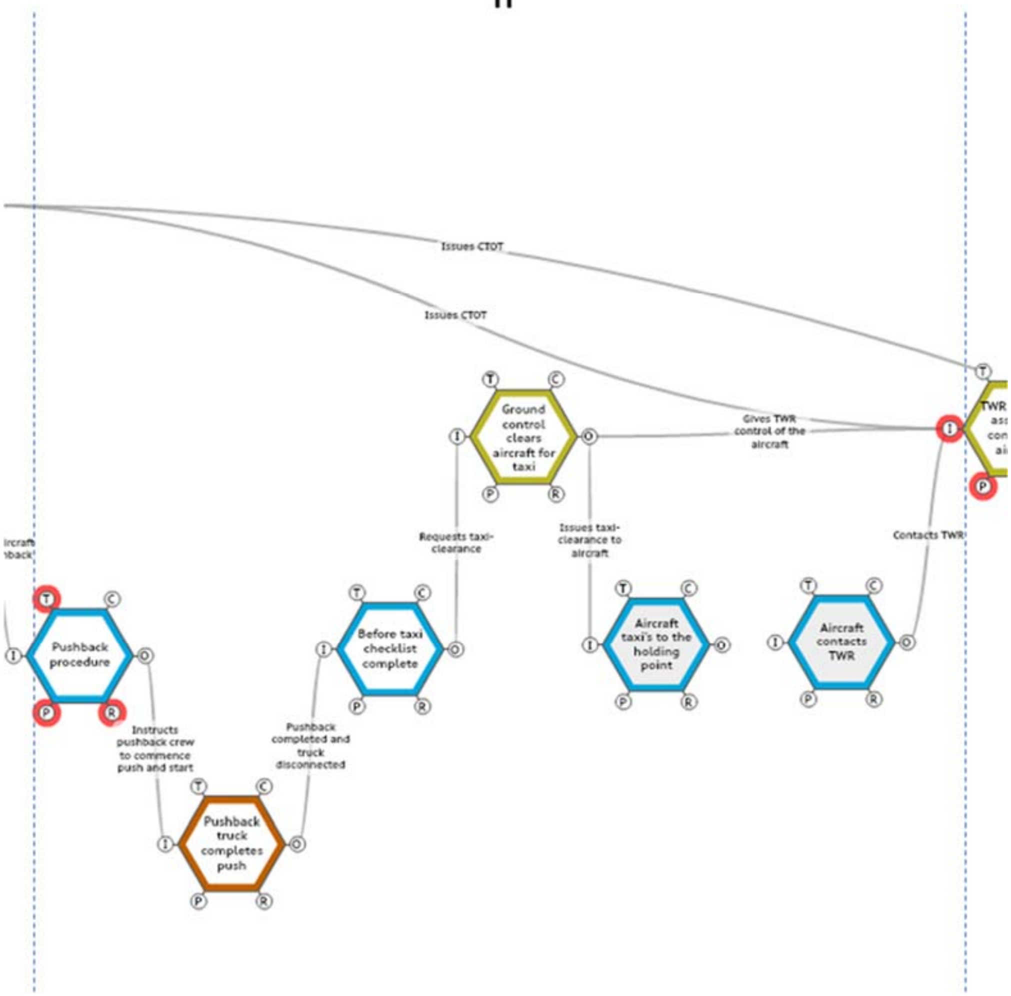

Figure 15. Center part of the FRAM model.

III

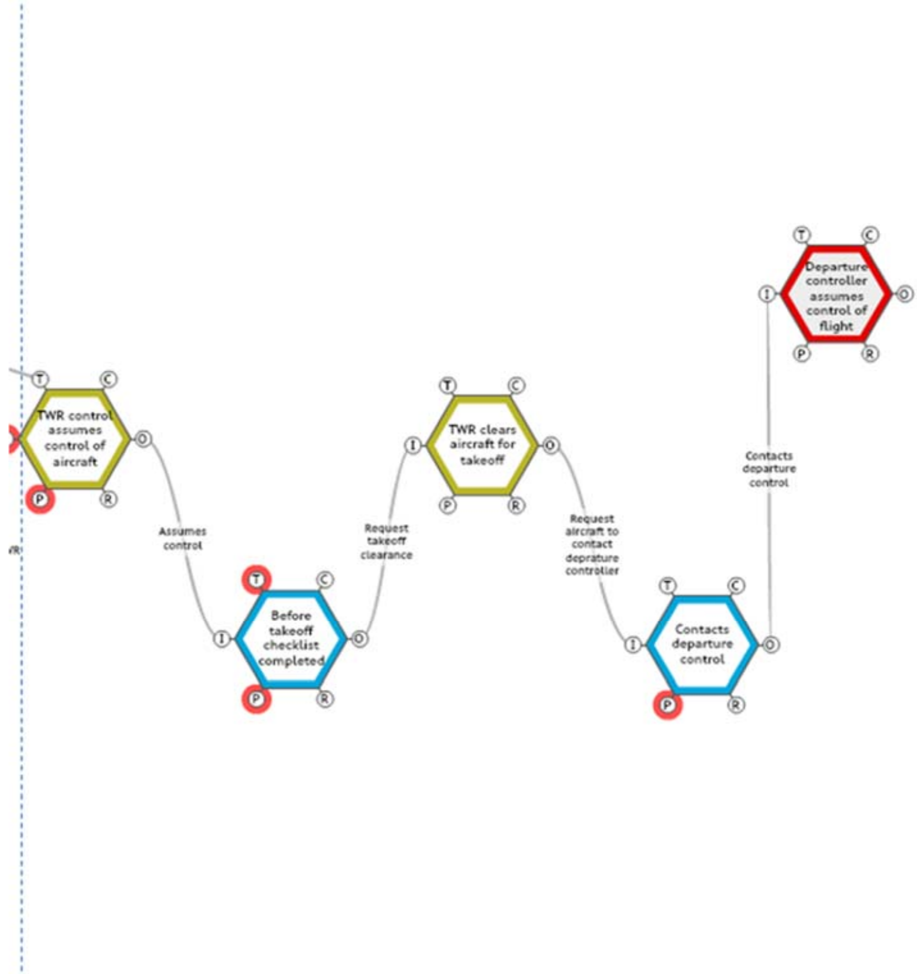

Figure 16. Right part of the FRAM model.