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# **Case Study: Digitization of a User Interface**

Investigating the use of a touch screen in  
Helicopter 14

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KTH Industriell teknik  
och management

## Examensarbete TRITA-ITM-EX 2020:165

### Fallstudie: Digitalisering av ett användargränssnitt

Undersöker användningen av en touchskärm i Helikopter 14

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Godkänt 2020-05-02	Examinator Claes Tisell	Handledare Anders Hedman
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## Sammanfattning

Ett användargränssnitt bör vara intuitivt för att uppgifter ska kunna utföras på ett effektivt och säkert sätt. I Helikopter 14 (HKP 14) finns operatörskonsoler med ett användargränssnitt som kallas Programmerbara Knappar (PK). Dessa styr det ledningssystem (MMS) som finns ombord på helikoptern. Att ersätta det nuvarande användargränssnittet med en touchskärm har föreslagits. För att förstå operatörernas arbete i sin kontext har den här fallstudien genomförts med inspiration från etnografi. Det nuvarande gränssnittet har studerats teoretiskt genom att läsa systemmanualer och praktiskt genom demonstrationer av ledningssystemet i Saabs testrigg och i HKP 14. Fallstudien avser att hitta vilka möjligheter och begränsningar som uppkommer i samband med att gränssnittet ersätts med en touchskärm. För att undersöka olika perspektiv på användandet av en touchskärm i HKP 14 har intervjuer genomförts med operatörer och en flygtekniker, samt anställda på FMV och Saab. Studien visade att det finns både för- och nackdelar med att implementera en touchskärm i helikoptern. En återkommande farhåga med touchskärmar var att de saknar fysiska referenspunkter. Denna studie ger förslag på hur taktil återkoppling kan uppnås på en touchskärm och exemplifierar hur det digitala användargränssnittet kan se ut med hänsyn till detta.





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## **Abstract**

A user interface should be intuitive to allow efficient and safe execution of tasks. Helicopter 14 (HKP 14) has operator consoles with an analog user interface, called Programmable Keys (PK), to control a Mission Management System (MMS). The idea of replacing the PK with touch technology has arisen. To understand operators' working environment, this case study was conducted with inspiration from ethnography. The PK have been studied by reading system manuals and familiarizing with the MMS in Saab's test rigs and in HKP 14. This study aims to investigate the opportunities and challenges with implementing a touch screen to replace the current PK. Interviews have been conducted with operators and one technician working with HKP 14. To highlight additional perspectives on usage of touch technology, interviews with employees at FMV and Saab were carried out. This study found both benefits and drawbacks with implementing a touch screen in the helicopter. The most common concern was that touch screens lack tactile feedback. This study exemplifies how physical support can be achieved on a touch screen and how a Graphical User Interface (GUI) can be designed with regards to this.



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## ABSTRACT

A user interface should be intuitive to allow efficient and safe execution of tasks. Helicopter 14 (HKP 14) has operator consoles with an analog user interface, called Programmable Keys (PK), to control a Mission Management System (MMS). The idea of replacing the PK with touch technology has arisen. To understand operators' working environment, this case study was conducted with inspiration from ethnography. The PK have been studied by reading system manuals and familiarizing with the MMS in Saab's test rigs and in HKP 14. This study aims to investigate the opportunities and challenges with implementing a touch screen to replace the current PK. Interviews have been conducted with operators and one technician working with HKP 14. To highlight additional perspectives on usage of touch technology, interviews with employees at FMV and Saab were carried out. This study found both benefits and drawbacks with implementing a touch screen in the helicopter. The most common concern was that touch screens lack tactile feedback. This study exemplifies how physical support can be achieved on a touch screen and how a Graphical User Interface (GUI) can be designed with regards to this.

## KEYWORDS

Tablet, Touch screen, Human-Computer Interaction, Graphical User Interface, Helicopter

## DATABASES

Association for Computing Machinery, IEEE Xplore Digital Library, Google Scholar, KTH Library Primo

## 1. INTRODUCTION

Digitization within avionic systems is an ongoing process and it has become more common to implement touch screens. Thales [30], Honeywell [17], and Rockwell Collins [25] have applied touch technology in cockpit displays. According to Saab, it is of interest to investigate touch technology for the helicopter NH90S, which is used by the Swedish Armed Forces. In Sweden NH90S is known as Helicopter 14 (HKP 14). A touch screen can potentially replace the current user interface that consists of Programmable Keys (PK) on operator consoles in HKP 14. As of today, the PK have a very limited amount of spare parts which cannot be manufactured anymore, and the maintenance is complex. In general, the helicopter environment implies high demands for new technology.

Situational awareness and management of safety critical tasks have been investigated by studying touch screens in helicopters [2, 3, 8], aircrafts [6, 5, 26] and cars [21, 4]. It is known that touch screens lack tactile feedback [10, 11]. This is an essential aspect to be able to look elsewhere while working with an interface [10]. Accidental touches may occur in a vibrating environment [2], which also needs to be taken into account in this case.

In this study, interviews, observations, and tests were conducted with users and employees at Saab and FMV to collect different perspectives on usage of touch technology on operator consoles in HKP 14. The purpose of this case study is to investigate the opportunities and challenges with replacing the current PK with a touch screen.

## 1.1 Background

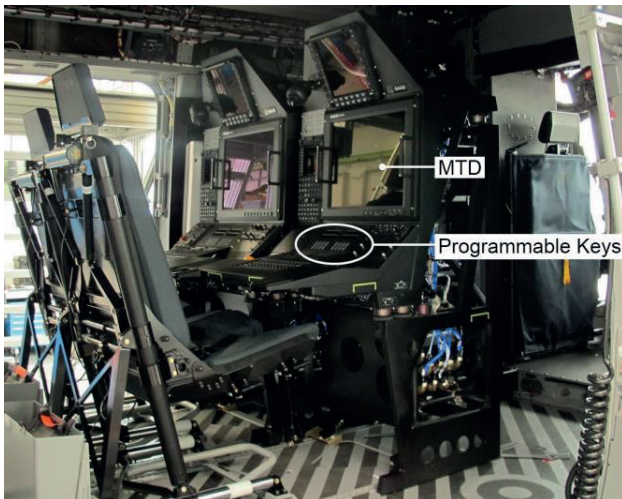
The following chapter covers relevant information and key components that the operators use in their work. The information in this section was provided by Saab [Fredrik Masus, Personal Communication, 2020-01-15]. The abbreviations and terminology used in this paper can be found in appendix I.

### 1.1.1 The Tactical Mission System in HKP 14

HKP 14 is equipped with a Tactical Mission System (TMS) and the system development was initiated in 2002 [27]. The helicopter can be used for: transportation of workforce, Search and Rescue (SAR), firefighting, Anti-Submarine Warfare (ASW), medical transport, and surveillance of water, ground, and air. The crew constellation depends on the type of mission and the interior is therefore modular.

### 1.1.2 The Operator Console in HKP 14

The helicopter can be equipped with one or two consoles, each operated by an operator. The operators have different responsibilities but work cooperatively to control the Mission Management System (MMS). The MMS is a part of the TMS and displayed at the Main Tactical Display (MTD). The two consoles are identical, which means that the two operators have access to the same functions, see figure 1.



**Figure 1. The console with callouts on the MTD and Programmable Keys. Image provided by Saab.**

### 1.1.3 The Programmable Keys (PK) on the Console

The PK are a quick way to enable functions and make adjustments in the MMS. Some PK activates pop-up windows on the MTD where data can be displayed or typed in manually with the keyboard. The keys are 15x15 mm and lowered in the console with facets, see figure 2. The 32 PK allow over 240 functions since the first row of the PK are menu keys that holds a set of sub-functions. The MMS can alternatively be managed with a trackball and a physical keyboard on the console. The PK allow operators to work with multiple things at the same time on the MTD.



**Figure 2. The Programmable Keys with 32 keys and eight displays. Image provided by Saab.**

## 1.2 Delimitations

The delimitations in this case study are:

- This study was limited to 20 weeks, which affected the involvement of the end users.
- The created prototypes and concepts are based on the tablet MilDef DS11 [19], which Saab uses for prototyping and is a potential substitute to the current PK.
- This study focuses on investigating opportunities and challenges with a touch screen for operator consoles in HKP 14.

## 2. THEORY AND RELATED RESEARCH

In order to understand the working environment in HKP 14, it is of importance to look at similar systems that require accuracy, precision, and easy usage to execute tasks in a safe and correct way. This section provides research done on user interfaces and touch screen usage in helicopters, airplanes, and cars.

### 2.1 Consideration of the Context

Vibrations and weather can affect the usability of a touch screen in a helicopter [2] and during the winter pilots operate in an environment which is more turbulent [3]. In a safety critical working environment, intangible human capabilities may be too valuable for the work to disappear when digitizing a system. In 2000, MacKay [18] observed controllers in air traffic control rooms to investigate if digitization was a suitable option. The study showed that the use of physical paper flight strips was a safe system already. These strips allowed controllers to memorize them visually when moving them around. Additionally, the social aspect was found essential in the working environment. MacKay observed that, good situation awareness can be achieved by knowing your colleagues' strengths and weaknesses, but also their daily capability to predict behaviors and distribute the workload. Therefore, it is of importance that software engineers understand the context and safety issues of a current analog system and not get too blinded by the benefits that software can provide [18]. In connection to this, Dourish [13] recommend using ethnographic methods to see the real world, understand the surroundings, and social context. Especially within Human-Computer Interaction (HCI) [13].

### 2.2 Digitizing Analog Systems in Aircrafts

An Electronic Flight Bag (EFB) is a digital device used in avionic systems to replace physical paper documents, which previously were stored in the pilot's bag during flight [14]. The EFB can be divided into two categories: portable and installed [16]. A portable EFB was preferred by pilots because of its usability and have a cost advantage since it requires less certifications than an installed one [22]. Depending on the required usage, the EFB can be divided into: type A (no safety effect) and type B (minor safety effect). Neither type A or B can replace systems or equipment needed for airworthiness. EFBs cannot have a negative impact on safety if failure occurs and need to pass Electromagnetic Compatibility (EMC) tests before being implemented [14].

In 2003, Boeing introduced an installed EFB which was considered to have positive effects on safety, efficiency, and workload [5]. An EFB was at this time managed via physical buttons on the frame of its display, and provided pilots with figures, graphs, videos, and documents [6]. Today, cockpits are designed with both integrated and portable touch screens [3]. For example, pilots in the Spanish Maritime Safety Agency use portable tablets with touch screens as EFBs in helicopters to perform checklists and access weather information. A study made on this showed that such a device was appreciated by some pilots since it collects important information at one place which is easy to access. However, other pilots in the same study were skeptical to use tablets with touch during missions since the interaction requires the user to look at the screen. This may distract the attention from other tasks. The helicopter's movement can cause accidental interaction with the touch screen. However, resistive touch can be used to minimize the risk of unwanted selections in a vibrating environment, while capacitive touch is more sensitive [2].

### 2.3 Eyes-Free Interaction with a Touch Screen

Colley et. al. [10] consider tactile feedback important when performing tasks where a user have to operate a touch interface while looking at another screen. In this study they investigated how to improve eyes-free interaction on touch screens. This was conducted by placing a plastic sheet with cut-outs on the screen to guide the touch interaction. This increased the ability to look elsewhere. The result showed that the test participants thought it was easy to use and felt safe considering the possibility of accidental touches. The test result showed no clear difference considering time to complete the task between normal touch and guided touch [10].

#### 2.3.1 Haptic Feedback in Avionics

Haptic technology provides mechanical force feedback and is suitable for vibrating surroundings such as an avionic environment [7]. A study on the subject found that the sensation of pushing a virtual button on a haptic touch screen is considered to be as efficient as pushing a mechanical button. This was tested in a simulated environment that resembles a vibrating helicopter [8].

#### 2.3.2 Touch Screen Usage in Cars

The automotive industry is another area where touch screens are implemented. One example is the Tesla

Model 3 where functions are monitored via a touch screen integrated in the dashboard. A software system allows design freedom and quick updates. However, the in-vehicle touch screen may distract the driver's attention from the primary task, focusing on the road [21]. Cars are today equipped with touch screens to regulate temperature, radio, GPS, and other features. Bach et. al. [4] made a study on the subject that showed that touch screens with digital buttons are efficient for completing tasks in cars. However, it was found that the touch interaction requires the driver to look at the screen, in most cases for 2 seconds or more. If the touch screen was operated by gestures, such as swiping and double tapping, it required fewer and shorter eye glances. Tasks performed by gestures were easier to complete without looking, which increased focus on the road. This technique was considered intuitive and safe by users. In contrast to touch screens, the study also showed that buttons and knobs on an analog stereo interface required more visual attention. The study suggests exploring combinations of different interaction techniques e.g. gestures, tactile and/or digital buttons to achieve an optimal design [4].

## **2.4 Guidelines for a User Interface**

According to guidelines from the Federal Aviation Administration (FAA) it is important to display the information on a Graphical User Interface (GUI) with consistency e.g. in the use of color, size, labels, and symbols. This should also be in line with other GUIs in the flight deck [15].

Clutter occurs when a display contains too much information and graphical elements. This could mislead the user's attention from primary tasks. If this is avoided, the work can be performed more efficiently, and errors can be minimized [15]. To facilitate decision making, helicopter pilots preferred to have as few steps as possible to access functions [2]. Additionally, the readability on the GUI should not be affected by environmental conditions [15].

### **2.4.1 Use of Colors**

The choice of color has a strong impact on the information transfer and should be standardized to avoid confusion and misinterpretations. For example, red is associated with alarms for danger and potential threats while green is a desired and acceptable state that requires less attention. It is recommended to not use more than six colors when color coding. Combinations of

navy blue/black and yellow/white should not be used because of the small difference in luminance. Background color should be selected to not interfere with the color of other elements on the display [15].

Good vision is important for situation awareness during flight. To improve vision in darkness, avionics commonly use Night Vision Imaging Systems (NVIS), which amplify the ambient light intensity. Therefore, lighting and displays in avionics have to fulfil some standards [28]. The NVIS is divided into different classes and they only allow usage of certain wavelengths [12].

### **2.4.2 Recommended Button Size**

The helicopter is exposed to more vibrations than airplanes with fixed wings. Therefore, touch buttons and their labels should be large enough to be operated in a vibrating environment [2]. Avsar, Fischer, and Rodden [3] recommend a button size of 15x15 mm on a touch interface for non-safety critical tasks in a helicopter. For safety critical tasks 20x20 mm buttons are recommended [3]. The US Department of Defense (DOD) recommends a button size between 15x15 mm and 38x38 mm for bare hands. For gloves, they recommend increasing the dimensions with 5 mm. Spacing between buttons may be 3-5 mm for touch screens where the button actuation happens when the finger is released. If the button actuation is initiated by the first touch, the spacing should not be smaller than 5 mm [11]. However, it is recommended to not exceed the suggested button size, since it will not improve the performance. Instead, it is suggested to add a confirmation step to increase safety [3].

### **2.4.3 Use of Labels and Symbols**

Symbols should be clearly differentiated from each other and not cause misinterpretations [15]. The combination of text and symbols have been found to have positive effects on learning considering time and ease of use, especially when a user is new to the interface [31].

## **2.5 Research Question**

Clearly, touch screens have potential to be applied in several contexts, but there are some drawbacks which are important to acknowledge. Therefore, it is essential to consider the environment before implementing a new digital solution. As mentioned in the introduction, section 1.1, the aim with this study is to investigate the opportunities and challenges with implementing a touch screen at operator consoles in HKP 14.

### 3. METHOD DESCRIPTION

The method used in this study was inspired by the phases in Design Thinking, which consists of: Empathize, Define, Ideate, Prototype and Test [29]. It was also inspired by an ethnographic way of describing the context [13, 18] through observations and interviews. In parallel with this, related research and theory were examined. Insights from previous research and the conducted interviews were tested and exemplified by creating prototypes and concepts.

#### 3.1 System Introduction and Site Visit

The project started with introductions and demonstrations of the TMS, MMS and PK at Saab's test rig. After this, the system was studied further by reading several system manuals provided by Saab. This was followed by a visit to the Swedish Armed Forces at F17 in Ronneby. The visit took place over two days. During the first day, observations were made outside and inside HKP 14. Interactive demonstrations of the TMS and PK were performed in the helicopter by Saab employees. The hangars and the training simulator were also visited. The second day, interviews were conducted with three Tactical coordinators (TACCO), one Sonar operator (SENSO) and one Technician in flight (TIF). The interviews were carried out in groups of 2-3 people in a conference room during approximately two hours each. A tablet, MilDef DS11 [19], with all existing PK was used as trigger material during the interviews. A3 papers with all PK functions were used by both respondents and interviewers to take notes on. The two interviews were analyzed through affinity mapping, see appendix II.

#### 3.2 Interviews with FMV

The potential usage of a touch screen in HKP 14 was complemented by interviewing employees at FMV, the Swedish Defense Materiel Administration. FMV verifies product safety and usability for the Swedish Armed Forces. One of the interviewees at FMV had theoretical knowledge about the TMS. The other three had experience in using the PK and other parts of the system as well as observing operators working with them, both on ground and during flight. In addition, one of them had previously worked as an operator. One interview was carried out with two employees and two were individual. All interviews lasted for approximately one hour via phone due to travelling restrictions, caused by Covid-19.

#### 3.3 Interviews with Saab

The internal knowledge at Saab was also explored. One interview was conducted with three employees at Saab that worked with the development of a digital interface on the marine operator consoles. The interview lasted for two hours and included a demonstration of the touch screen on the marine console. The demonstration was held by one interviewee without being recorded.

Another interview was conducted with a Saab employee that is responsible for the industrial design and product demands of the display systems in Gripen. The interview took approximately one hour via phone.

All interviews in this case study were semi-structured [20] to allow flexibility, although an interview guide was used. One interviewer was leading the interview while the other was taking notes and asking additional questions. All interviews were recorded and transcribed. In the transcribed text, key words and sentences were highlighted and further analyzed. The result from each interview was confirmed by the interviewees afterwards.

#### 3.4 Interaction-Guide-Test

The insights from the interviews were followed by a prototyping phase. Interaction guides [10] were created to test tactile feedback on a touch screen. Four different interaction guides were made of sheets in clear PET or acrylic with 0.5, 1, 2, and 3 mm thickness. These guides were laser cut, see templates and test procedure in appendix III. During the test, the participants wore gloves made of goat leather [9], see figure 3 on the next page. The tests were conducted individually with ten Saab employees working with the TMS in HKP 14 and lasted for 30-60 minutes. Seven of the ten tests were conducted by one interviewer and the other three were conducted by two. An interview guide was used during the tests and notes were taken.



**Figure 3. An interaction guide placed on the MilDef tablet during the interaction-guide-test.**

### 3.5 Ideation of Graphical User Interfaces

Brainstorming and brainwriting were used to generate ideas for new functions and layouts of a touch interface. These ideas were later combined into five different GUIs. These were drawn on paper and used for paper-prototype-tests, see figure 4. During the tests, one prototype was shown at a time and the respondents had time to give feedback. The test procedure can be found in appendix IV. The test was conducted individually with six employees at Saab working with the TMS and lasted for 30-60 minutes. One of the six tests were conducted by one interviewer and the other five were conducted by two. Notes were taken during the test.



**Figure 4. During the paper-prototype-test drawings of the GUI were placed inside a cardboard frame.**

Based on the findings from the conducted prototype-tests, three interactive GUI concepts were created. These allowed touch interaction and actuation of certain functions on a tablet. The GUI concepts were created in Adobe XD [1]. The full concepts can be found in appendix V, VI, and VII.

## 4. RESULTS

In the following section the results from the interviews with users at F17 and employees at FMV and Saab are presented. Results from the prototype-tests and the developed concepts are also presented.

### 4.1 Operators in HKP 14

From the two interviews at F17, the following roles were identified: Tactical coordinator (TACCO), Sonar operator (SENSO), Technician in flight (TIF) and pilot. The helicopter is suited for one pilot, one co-pilot, one TACCO, one SENSO, and one TIF. The TACCO is responsible for tactical coordination and navigation, which includes preparing flight routes, managing tracks, and controlling sensors e.g. the radar and camera. The SENSO is in charge of the sonar system and uses the dipping sonar and sonar buoys to identify objects below the water. The TIF is responsible for maintaining the helicopter and ensuring that everything works, before, during, and after flight.

During flight, the crew wears insulating uniforms, life vests, flame resistant gloves, boots, earplugs, and helmets with integrated headphones. This equipment is a requirement. However, operators mentioned that the uniform is bulky and that they sit close to the console. This affects the comfort and ability to reach components. The TIF and the two pilots in the cockpit use Night Vision Goggles (NVG) to see outside in the dark. This means all equipment must be NVG compatible so as not to blind the crew.

#### 4.1.1 Operators' Usage of Programmable Keys (PK)

The operators prefer to work with the existing PK since they allow them to complete tasks quicker and to control many things while looking elsewhere. Both the TACCO and SENSO estimated their use of PK to 10-30% of their work. Despite this, operators are still not familiar with all available functions. The TIF does not normally work with the PK but has basic knowledge.

All TACCOs mentioned that the current PK design is not optimal. The PK display contains labels of functions that is not the actual key, the keys are placed below, which was considered confusing in the learning phase. Nowadays, operators are learning the PK in a simulator that holds the current PK design with displays and keys on a Surface Pro tablet. During the interview one TACCO pointed out that the PK are being used more frequently by younger operators.

#### 4.1.2 *The Context and Working Environment in HKP 14*

During the site visit at F17, the working environment in the hangar and HKP 14 were observed. A loud noise level was noticed just from starting up the electricity in the helicopter, due to the computers' cooling systems. When the engines start, the sound level is even higher according to the TIF. An observation inside the helicopter revealed that laminated paper sheets were put up on the consoles to take quick notes on. In interviews, all operators said that they use a notebook and a pen to take quick notes during flight. The notebook is placed on top of the keyboard since the console does not allow any free desk space. They usually put the pen in their mouth or wherever they can since storage is limited. The SENSO described that all required paper documents e.g. protocol and manuals are kept in a bag that is tied to the operator's chair.

During the interviews, operators explained that the helicopter has small and frequent vibrations during flight but clarified that the environment onboard is not as shaky and turbulent as one might think. The consoles and console chairs are suspended which makes the performance of tasks rather stable. One TACCO stressed that flight safety always has the highest priority. It is important that the crew can act quickly to avoid sudden obstacles. Emergency maneuvers are practiced and should be intuitive when needed. All respondents explained that they do not want to complete safety critical tasks with PK, e.g. controlling the dipping sonar up and down or cutting off the wire if it gets stuck.

#### 4.1.3 *Opportunities with Using a Touch Screen in HKP 14*

All operators thought that a software solution would be more flexible. Two TACCOs said that more functions could be implemented and one of them suggested adding a screenshot function. The SENSO saw the opportunity to take notes on the touch screen with the finger. Both the SENSO and TIF suggested storing manuals, protocols, error codes, and other useful files as PDFs on a tablet in the helicopter. A built-in search function connected to the keyboard was requested. They also suggested using a portable tablet as a storage unit to transfer mission data, since a heavy external laptop is currently required. Two TACCOs thought that a tablet could be used for preparing a mission anywhere on the ground, before flight.

All operators requested the ability to categorize and arrange the virtual keys in their own personal way. One TACCO suggested adding a key called OWN and said, "... we are individualists regarding the way we use them.". The TACCOs thought that personal settings could be achieved by creating personal logins where favorite keys are saved, like the equivalent system in the Corvettes made by Saab, which is controlled via a touch screen. However, one TACCO and the TIF highlighted the importance of having a consistent base layout to allow recognition. It is also of importance to consider accessibility and not hide functions in submenus, according to the TIF.

#### 4.1.4 *Challenges with Using a Touch Screen in HKP 14*

A major concern among all operators was that touch screens lack physical feedback. They do not provide any physical support to find keys. The TACCOs wanted the focus to be on making the solution as intuitive as possible by ensuring muscle memory. This would allow them to focus more on the MTD. One TACCO said that it is important to find keys without looking and suggested adding a grid for physical support on the touch screen. Physical keys are more likely to be operated without looking, according to the TIF and one TACCO. Because of this, they preferred physical keys. Still, all operators spend time looking down to find the right PK and two expressed the need to confirm the actuation by looking at the display on the current console.

All interviewees were concerned about using touch since operators wear gloves made of goat leather and Nomex, see figure 5. One TACCO described that worn gloves do not always have a good fit to the fingers which lowers the precision and the tactile feel. However, it is required to use gloves, but all operators mentioned that the tactile feel decreases when working with them. Some remove them to easier execute certain tasks, e.g. typing on the keyboard to avoid faulty presses. All respondents preferred the feedback from the existing physical keyboard and wanted to keep it. They also stressed that gloves and touch technology need to be compatible. Touch PK were not considered to affect the time to complete tasks by SENSO and TIF. However, two TACCOs were concerned about accidental touches, especially regarding using a tablet in turbulent situations. The SENSO did not want to say if a touch screen would be

suitable for the helicopter environment before it is tested. Another challenge, highlighted by the SENSO and TIF, was that a portable tablet requires more attention regarding safety routines since it might become confidential.



**Figure 5. Flame resistant gloves used by operators.**

All respondents thought that vibrating feedback was a possible complement to touch but neither of them were convinced that this would be enough. The SENSO suggested having sound as feedback but mentioned that such an option is unlikely to be universally popular so it would have to be optional. Two TACCOs and the TIF discussed using a blinking indication when selecting a function. The SENSO also wanted a clear indication of key selection and suggested inverting colors of the key and label, as the current system. One TACCO thought that color coding may increase clarity and suggested combining text with symbols. The key size also matters, since bigger keys allow less precision, according to the TACCO. However, all operators expressed that the digital PK should not cause clutter, meaning not using an extensive number of keys, colors, and labels.

#### **4.1.5 Limited Involvement of Operators**

When conducting technology transitions, it is important to understand the environment the users are operating in. It was not possible to involve operators at F17 to the desired extent due to lack of time. This will be further discussed in section 5.4.1.

## **4.2 FMV's Perspective on a Touch Screen**

The result from the interviews with FMV reflects an additional perspective on the usage of PK and touch screens. Two interviewees explained that if a touch screen were to be installed in the helicopter the usability needs to be assessed by both test engineers and operators. The touch screen would have to pass tests in labs, simulators, and the helicopter on ground and in flight. FMV would test that the tablet is robust enough, work as intended, and not cause damage to other systems. Another interviewee explained that the PK were placed flat on top of the console in the development phase, which resulted in lack of physical feedback. Therefore, the PK were lowered in the console as the current design. Since the current design frames the keys, faulty actuations were considered rare, even though the helicopter environment can cause the hand to vibrate. Having control of the situation and to be able to act in emergencies was expressed as essential for operators.

### **4.2.1 Opportunities with Implementing a Touch Screen**

All interviewees agreed that a touch screen would allow more functions than physical keys, e.g. two of them mentioned that the camera could be operated by hand gestures. One interviewee said that a digital interface allows more keys but thought too many functions should be avoided. Another one suggested that it would be useful to add a slider that enables the operator to adjust functions quicker. The possibility to take notes during flight, to view flight checklists, error codes and flight manuals via a touch screen was suggested by two interviewees. Everyone mentioned that a tablet can be used anywhere for preparation and evaluation of missions. Incorporating a keyboard and a numpad in the touch screen was discussed by two respondents, but they were not sure how or when it will be used.

### **4.2.2 Challenges with Implementing a Touch Screen**

All interviewees expressed that the touch screen needs to be compatible with gloves, which affect the tactile feel and make the fingertips less sensitive. The mechanical force feedback is considered important by all but can be difficult to achieve on a flat screen. Since a touch screen lacks physical framing, two respondents suggested having digital keys that are large enough and not placed too close to each other. They also suggested framing the virtual keys and having such a frame removable.

The ability to process and execute tasks through touch must not degrade safety according to one respondent. Two respondents recommended to avoid incorporating functions that can cause serious consequences if they are activated by mistake. A touch screen should be a secondary interface to make adjustments and not replace primary panels according to them.

Having the touch screen integrated in the console was preferred by two interviewees. They thought there is a risk that the tablet will not be mounted correctly, and that dirt will become stuck when flying with open doors. The risks of dropping or losing the tablet were highlighted by three respondents. Two of them also mentioned that if data is saved on the tablet the device could become confidential.

Despite the concerns, all interviewees from FMV were convinced that touch technology has potential to be used in the helicopter. One interviewee referred to adolescents, who are exposed to touch screens daily, which makes the learning barrier smaller.

#### 4.2.3 *Desired Feedback from PK*

Two of the interviewees did not consider the feedback on the current system optimal. When pressing a key there is a small mechanical force feedback but they explained that users often want to verify the selection by looking at the PK displays. Additionally, the existing PK do not display all functions at once and one respondent had noticed that operators tend to search for functions in the wrong PK menu for a few seconds. The same interviewee also thought the labels on the current PK are small and briefly explained, which may affect the usage.

Visual feedback was considered necessary. Actuation of a key could e.g. be visualized with a blinking indication, which was suggested by three respondents. The fourth interviewee wanted visual feedback for immediate response. Vibrating feedback was discussed by three interviewees as a possible solution. Sound was not a preferable option by any of the interviewees at FMV since it might not work as intended in the helicopter environment.

### 4.3 **Operator Consoles in Corvettes**

The three interviewees from Saab's naval department provided information about the operator consoles in the Corvettes. The Corvettes perform many different types of missions, e.g. ASW missions as HKP 14. Today, these ships have consoles, called Multi Function Console

(MFC), with a main display and a fixed integrated touch screen. The operators execute tasks via the touch screen, called Touch Input Display (TID).

#### 4.3.1 *The Touch Input Display (TID)*

Originally the console interface consisted of physical buttons. The TID was first implemented in the 90's and had 25 buttons. Market requests may have been a reason for implementing a touch screen according to two respondents. Many generations of the interface have been developed and the number of buttons has increased.

Today, the interface on the TID consists of different menu tabs that include different functions. Buttons that have a direct impact on the system have a confirmation step before activation. One interviewee described that a touch button is activated when the user releases the finger from the screen to increase safety. The interviewees explained that the system architecture was designed with regards to standards and guidelines for ergonomics and Human-Machine Interface (HMI). In these types of projects, workshops are arranged with users and customers to evaluate new designs.

#### 4.3.2 *Benefits of a Touch Input Display (TID)*

Before touch was introduced, each console was dedicated to a specific role and contained different sets of physical buttons. One interviewee described that touch technology made it possible to make the console multi-functional. This also created redundancy. Before the system was digitized, the space for functions on the console was limited. This increased the need for a flexible solution, according to one respondent. All interviewees described that the touch screen allows a flexible rearrangement of functions. The TID allows operators to save a customized layout to their personal profile, which is an appreciated feature by operators according to one of the interviewees. The TID also allows quick access to view documents on the main display. Another interviewee said that the touch display has resistive touch, which works well with the gloves that operators wear for flame protection.

#### 4.3.3 *Drawbacks of a Touch Input Display (TID)*

One interviewee said that the drawback with the TID is that all functions cannot be visible at once, as in the analog system. Today, operators have to search in different menus to find certain functions, which was considered inefficient. The same respondent mentioned

that the physical buttons were lit up when activated, which provided good visual indication. Errors were indicated by blinking which made it easy to locate them. There is also a risk of accidental touches on a touch screen when waves are high due to harsh weather, according to the respondent. Physical keyboards are still used on the consoles since a touch keyboard requires eye interaction and lacks physical references. Because of this, the respondent considered touch keyboards problematic when operators have to write large quantities.

#### **4.4 Implementation of a Touch Screen in Gripen**

The interview about the implementation of a touch screen in Gripen highlighted another perspective on touch screen usage. The interviewee explained that a fighter with an integrated touch screen is being developed in Gripen E, and it is an ongoing process to decide what functions the touchscreen will provide. The respondent explained that users are involved in both initial and final tests for new products or updates to validate that functions are usable in their context.

The previous Gripen models have three small displays where the pilot can access functions via buttons on the frame of the displays. The same functions can be accessed via the throttle control and the control stick to operate the system without releasing them. The interviewee stressed that redundancy is important in this system to reduce the pilot's workload. The interviewee mentioned that customer demand was the reason for implementing the touch screen, but it was not necessarily needed. Despite the technology transition, the interviewee explained that it was decided to keep buttons on the frame of the touch screen since some might prefer to keep using them. Recognition is essential for pilots when transitioning to the new system. As of today, Saab is developing their own style guide for touch screens in Gripen based on MIL-standards and other guidelines to maintain consistency.

##### **4.4.1 Opportunities with Using Touch in Gripen**

A major part of a pilot's work is to maintain situation awareness via displays. The interviewee saw potential managing data, windows, and menus, e.g. by zooming in/out in maps and choosing objects through the touch display in a controlled flight mode. According to the interviewee, it is also possible to incorporate the flight manual in a touch screen. However, the respondent assumed that the touch screen will be more utilized before takeoff, when preparing a mission.

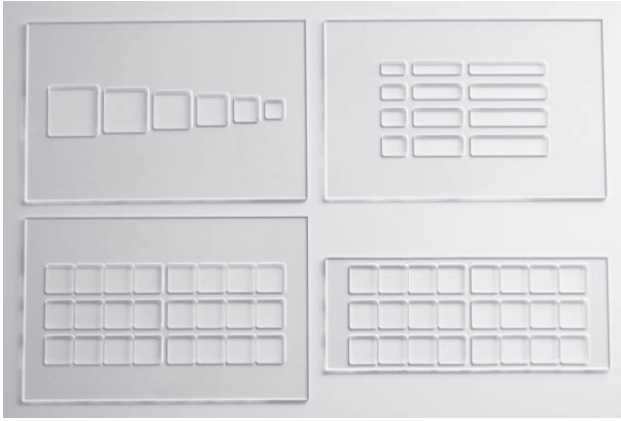
##### **4.4.2 Challenges with Using Touch in Gripen**

According to the interviewee, the interaction with a touch interface cannot be too complex during flight since the major task is to fly the plane. In stressful situations, pilots may not always make the quickest selections on the displays. A fault actuation must not imply any danger, and if a function has a severe consequence, a confirmation step is required. Touch buttons should not blink unless they should indicate that the pilot needs to switch attention to that immediately. The interviewee considered tactile feedback important in aircrafts, but difficult to achieve on the touch display since gloves are required.

Considering civil airplanes, the interviewee explained that it is difficult to use integrated touch screens on flight panels during flight, due to the shaking environment. In contrast to pilots, the interviewee highlighted that operators in HKP 14 work with tactical tasks, which creates other conditions for using a touch screen.

#### 4.6 Interaction-Guide-Test

The lack of tactile feedback on touch screens was further investigated since many of the interviewees considered this a drawback. Prototype tests were conducted with inspiration from the study about guided interaction on touch screens [10]. This test was conducted to evaluate the thickness of interaction guide and key size of the PK. The size of a slider function was also tested since one respondent from FMV suggested to add this function, as an optional way to make adjustments in the MMS. The tested interaction guides can be seen in figure 6. As explained in the Method Description, section 3.4, interaction guides with a thickness of 0.5, 1, 2, and 3 mm were tested. The full test procedure and templates of the interaction guides can be found in appendix III.



**Figure 6. The tested interaction guides in plastic for key size, slider, and interactive GUI prototype.**

##### 4.6.1 Thickness of The Interaction Guide

The participants had mixed opinions considering preferred thickness of the interaction guides in plastic, see table 1. Three participants preferred two different thicknesses on the interaction guide. Therefore, the median value of each participant was calculated before the total median value. During the interview six participants expressed that the 3 mm thick interaction guide was too thick. The 0.5 mm thick guide was considered too thin by eight participants, with regards to physical support, and difficult to sense with the gloves.

**Table 1. The median value of participants' preferred thickness of the interaction guide and preferred dimensions of key and slider.**

Participant	Thickness [mm]	Key size [mm]	Slider height [mm]	Slider width [mm]
1	1.5 (1&2)	20x20	16	63
2	2	20x20	14	63
3	1	20x20	16	63
4	2.5 (2&3)	20x20	16	63
5	2	20x20	14	63
6	1	20x20	16	63
7	1	15x15	10	63, 40, 20
8	2.5 (2&3)	25x25	16	63
9	1	25x25	14	63
10	1	20x20	12	63, 40, 20
<b>Total median</b>	1.25	20x20	-	-

A question about preferred thickness on the interaction guide with sliders lacked complete notes from two participants. However, the thickness on the interaction guide must primarily be compatible with the cut-outs for the PK. The slider needs to have the same thickness, since the plastic sheet will hold both PK and slider. Therefore, the data regarding preferred thickness on the interaction guide for sliders were excluded in the result.

##### 4.6.2 Size of Key and Slider

Regarding the size of a key in relation to the preferred thickness of the interaction guide, seven participants preferred a key size of 20x20 mm, see table 1. Also, as seen in table 1, the largest slider (16x63 mm) was preferred by five out of ten participants. A 63 mm wide slider was preferred by eight, while two participants favored all and said that the length depends on the task. During the interview five pointed out that a longer guide provides better precision.

#### 4.6.3 Correlation Between Thickness and Size

A relationship between thickness of the plastic sheet, key size and sliders was found. A decrease in thickness tends to suit smaller sizes on keys and sliders. Participants found it difficult to interact with the touch screen when cut-outs in the plastic sheet were small and the plastic was thick. Three participants mentioned that a thinner plastic allows a more relaxed angle of the finger to press a key, while a thicker plastic requires a steeper angle from above. During the test, six participants experienced an increased sensitivity when interacting with the interaction guides without gloves.

#### 4.7 Graphical User Interface (GUI) Concepts

The insights from the interviews were exemplified by creating paper-prototypes and concepts of GUIs with and without an interaction guide. Many respondents had ideas of new functions, such as viewing PDFs. Taking notes during flight was an identified need and some thought this would be a useful function to add to a touch screen. The ability to save favorite keys was also requested. Operating the camera by hand gestures was another suggested function.

The PK on the paper-prototypes and the GUI concepts have a square shape with rounded corners, as the current PK. This was a suitable shape since recognition from a previous system was found important according to several interviewees. The keys are 20x20 mm, which were based of the result from the interaction-guide-test. Some of the functions are 15x15 mm, which is recommended for non-safety critical tasks [3]. The round keys on the GUIs have a diameter of 15 mm. The spacing between the PK are 3 mm, which is based on the recommendation by the US DOD [11].

##### 4.7.1 Paper-Prototypes

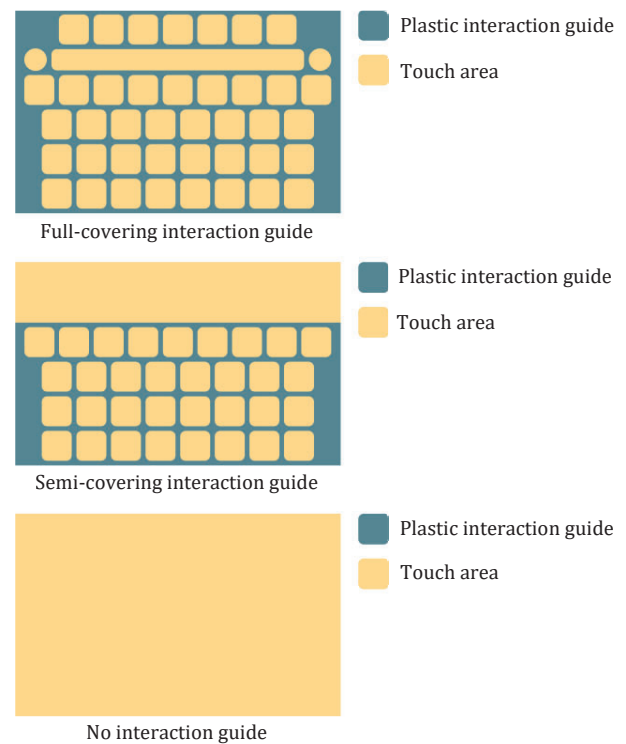
Five different paper-prototypes of GUIs were created and tested. Two paper-prototypes were designed for an interaction guide to achieve tactile feedback on the screen. One guide covered the entire GUI with cut-outs for keys and slider, called *Full-covering interaction guide*. Another paper-prototype had an interaction guide that covered the lower half of the GUI where the PK are placed, called *Semi-covering interaction guide*.

Additionally, three paper-prototypes were made of a GUI with no interaction guide, called *No interaction guide*. The five GUIs can be found in appendix IV, together with the feedback from the paper-prototype-tests.

##### 4.7.2 Concept Design of GUIs

The insights from the interviews and the feedback from the paper-prototype tests were refined to three interactive GUI concepts, which could be operated on a touch screen. By not going into details, the concepts aim for a simple and intuitive design.

One GUI concept was made for a Full-covering interaction guide, and another concept of a Semi-covering interaction guide. Both these concepts have a fixed interaction guide attached to the touch screen. The third GUI concept was designed without any interaction guide. In figure 7, the interaction guide is visualized with blue color and yellow visualize the touch area for the different concepts.



**Figure 7. Illustration of plastic interaction guide (blue) and touch area (yellow) for the three GUI concepts.**

All concepts include the current PK, arranged in a similar way, as the ones on the console. A dark grey color is used for inactive PK and light grey for active PK to visualize a key selection. A clear key selection was requested by both operators and FMV. The created GUI concepts have a login page where username and password can be typed. Operators requested a function where they could save their favorite keys, called OWN. Therefore, all concepts have this function. A confirmation step was also added to all concepts to increase safety and minimize accidental touches. The confirmation step is either activated or cancelled by pressing YES or NO. Common for all concepts is that they have a slider, which is an optional way to increase or decrease values. This feature was suggested by FMV. All concepts have new functions which allow easy access to view PDFs and write notes on the tablet instead of physical paper. The concepts allow taking screenshots on the MTD/tablet and adjust the brightness on the screen. These functions were also requested by the interviewees. The full concepts can be found in appendix V, VII, and VII.

#### 4.7.3 Full-Covering Interaction Guide

In this concept the GUI is fully adjusted to the interaction guide, see figure 8a and 8b. There are seven new functions at the top of the screen. The key for PDFs and notes will appear on the MTD since the interaction guide limits the desired readability and touch interaction for these. To visualize that the function will be viewed on the other screen, these keys have both text and icon. Notes can be written with the existing keyboard or the touch keyboard. See the full concept in appendix V.



**Figure 8a. The GUI concept with *Full-covering interaction guide* in plastic on a tablet.**



**Figure 8b. The design of the GUI concept with a full-covering interaction guide. In this view the key “NOTES” is selected and displayed on the MTD.**

#### 4.7.4 Semi-Covering Interaction guide

In this concept, the GUI is partly adjusted to the interaction guide, see figure 9a and 9b. This concept has an interaction guide on the lower half of the GUI and a free touch area at the top. This concept has tabs on the free touch area, which allow the PK to be used at the same time as something else is displayed on the upper part of the screen. Notes can be drawn with the finger on the free touch area, written with the existing keyboard or the touch keyboard. The tab called ATT.DATA can display flight navigation data on the free touch area. The tab named MTD has both text and icon to indicate that this function can be selected to display the tab views on the MTD. See the full concept in appendix VI.



Figure 9a. The GUI concept with *Semi-covering interaction guide* in plastic on a tablet.



Figure 9b. The design of the GUI concept with a semi-covering interaction guide. In this view the key "NOTES" is selected and displayed on the free touch area.

#### 4.7.5 No Interaction Guide

In this concept there is no interaction guide, see figure 10a and 10b. The GUI in this concept allows the user to save an extra row of favorite PK compared to the other concepts. Also, a key called ADMIN is added. The ADMIN key holds additional functions, such as browsing and viewing PDFs and notes. Notes can be drawn with the finger on the screen, written with the existing keyboard or the touch keyboard. The camera can be viewed and operated on the touch screen, as FMV suggested. Flight navigation data can also be displayed on the tablet and accessed via the ADMIN key. See the full concept in appendix VII.



Figure 10a. The GUI concept with *No interaction guide* on a tablet.

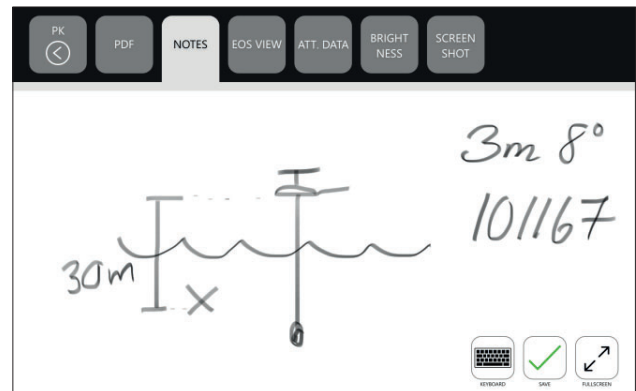


Figure 10b. The design of the GUI concept with no interaction guide. In this view the key "NOTES" is selected and displayed on the full screen.

## 5. DISCUSSION

The following section discusses insights from the background study and result to examine the opportunities and challenges with implementing a touch screen in HKP 14. Sources of error, sustainability aspects, and ideas for future work is also presented.

### 5.1 Touch Screens in Avionics

Evidently, touch screens are becoming increasingly common within avionic systems. For example, tablets are being used by helicopter pilots during SAR missions. Although pilots' primary task is to fly the plane, they manage to work with portable EFBs [2]. Pilots in Gripen also work with integrated displays but only in a controlled flight mode. In comparison, the operators' primary task is to work with the MMS at the consoles, not to fly. The environmental differences might also affect the usage of touch screens when comparing aircrafts and helicopters. Operators at F17 were not too concerned about the touch interaction due to vibrations since HKP 14 was considered stable during flight. However, the trackball can be used to access the same functions, even if it might be more time consuming than the PK.

### 5.2 Attitudes Toward Using Touch in HKP 14

The interviewees from F17, FMV, and Saab had different perspectives on touch screen usage in HKP 14. The operators tend to push more for an intuitive solution and the importance of muscle memory rather than if it is touch technology or not. This is interesting since customer demand was one of the reasons for implementing the touch screen in the Corvettes and in Gripen. However, various stakeholders are involved in these types of projects and it is not necessarily the end user who is the customer in this case. Despite the touch implementation, Gripen kept all physical buttons for pilots' recognition. As MacKay stated, human capabilities and the context of the working environment needs to be considered in the development [18].

Some operators at F17 were concerned about faulty actuations if a touch screen were to be used in turbulent situations, but the choice of touch technology can affect safety. Resistive touch can minimize unwanted selections [2] and is used on the consoles in the Corvettes due to its benefits. Enabling interaction by hand gestures is an option to allow less eye interaction with the screen [4] but could be difficult to achieve with resistive touch. Some interviewees at FMV highlighted the benefits of

having the touch screen integrated. On the other hand, a portable device has cost benefits [22] which can affect the final solution. Both operators and FMV mentioned that a tablet requires more safety management. Despite this, a tablet allows easy access to information in one place [2] and all operators wanted more, improved, or customized features.

#### 5.2.1 Touch Screens' Lack of Physical Support

One of the interviewees from FMV described that the PK originally were placed flat on top of the console, but that the physical feedback was not considered enough. If the current PK, with physical support, were to be replaced with a touch screen, it would likely result in the same conclusion: it lacks physical support. Therefore, an interaction guide can be a useful complement to touch. According to Colley et. al. an interaction guide enables the user to look elsewhere [10]. However, the interaction-guide-test made in this case study, confirmed that the gloves lower the ability to sense the guide.

Currently, operators learn the PK on touch screens in their simulator. If a touch screen were implemented in HKP 14, the system difference will disappear which might facilitate learning. Additionally, young operators use the PK more frequently which reflects the need of them, even in the future. Both operators and respondents from FMV expressed that the current design of the PK is not optimal. A redesign of the PK could potentially make them more intuitive and allow better feedback, preferably with inspiration from the benefits of analog user interfaces in this study.

### 5.3 Evaluation of the Created Concepts

The GUI concepts are suggestions rather than design recommendations. It was difficult to define which of the three concepts that would be most suitable since these have not been tested with operators. The intention with these prototypes is to engage a discussion between operators, Saab, and FMV.

All concepts have both benefits and drawbacks, and the final design will probably be a tradeoff between these. A delimitation for the GUI concepts was that the interaction guides were fixed attached to the display. The guide could potentially be removed when the flight mode is controlled, or when the tablet is used outside the helicopter, but mounting and storage have to be considered.

### 5.3.1 Interaction Guide or Not

The concept with the *Full-covering interaction guide* allows tactile feedback and muscle memory everywhere on the screen. This can potentially prevent faulty presses. As Colley et. al. said it provides the user guidance [10], which our case study confirmed since participants considered the thinner guides' feedback less distinct. In this study it was also found that an interaction guide affects the design freedom. All functions have to fit the cut-outs in the interaction guide, which is limiting. The concept with *Semi-covering-* and *No interaction guide* allow more functionalities, e.g. documents can be viewed on the touch screen, instead of the MTD. However, the *Semi-covering interaction guide* is a compromise between the two other concepts, although the free space is limited and may not be enough for operators to use as intended. The concept without any interaction guide allows greater utilization of the interface and a more inclusive design. For example, right- and left-handed operators can adjust the design according to their personal preference or the type of mission. Additionally, this concept has more potential to be used efficiently outside the helicopter. If an interaction guide is wanted and needed for this application, it would be beneficial to have it removable for increased usability.

When comparing a *Full-covering interaction guide* with the existing physical PK, the difference is not that significant. However, the question is if the trade off with limited interaction is worth the benefit of muscle memory. Another option would be to add haptic feedback, which has been proven to work in similar applications [7, 8].

### 5.3.2 The Design of the GUI Concepts

The GUI concepts are designed with consistency in mind to avoid clutter, considering colors, labels, and symbols according to FAA's recommendations [15]. Operators requested a consistent layout and not having too many functions, which the interviewee working with Gripen also considered important. Symbols are used in combination with labels since it is considered helpful [31]. All the PK on the three concepts have similar placement and a square shape with rounded corners for coherence and recognition from the current PK design. A transition to a system with similar design would lower the need for relearning. Some keys have a round shape to differentiate from the PK shape. The concept with a *Semi-*

*covering interaction guide* has tabs that are smaller than the recommended dimensions. However, they are considered non-safety critical and only used as additional functionalities. The PK are intentionally placed at the lower half of the GUI, closest to the operator since the PK are the most important functions.

Avsar, Fischer, and Rodden [3] and the interviewee working with Gripen suggested adding a confirmation step to increase safety, which is also used on the touch screens in the Corvettes. Therefore, a confirmation step was added to all concepts. Another aspect considered in the concepts, was the ability to access functions with as few steps as possible [2]. The colors on the GUI are not specified yet since they probably has to be NVG compatible. Parts of the crew use NVG and therefore, the system has to fulfil standards for NVIS [28, 12].

The GUI was designed according to the tablet MilDef DS11 [19] since Saab uses it for prototyping. If the interface on the tablet had other dimensions or if it was possible to integrate more than one tablet, the GUI might have looked different.

## 5.4 Source of Error

In this case study, interviews, observations, and prototype tests have been conducted. Below, the method and improvement areas are discussed.

### 5.4.1 Operators' Involvement in the Study

This study is based on subjective reasoning from the interviews. However, greater involvement of operators would have resulted in a more confident conclusion. The initial idea was to incorporate more methods connected to ethnography as Dourish advocate [13], e.g. using cultural probes, video recordings and conduct observations of the users at F17 during flight.

Operators were not involved in the prototype-tests and therefore, it was not possible to reflect their perspective on the interaction guides or the GUI concepts. The tests in this study were conducted with employees at Saab since the contact with users was limited. However, the test participants had good system knowledge and understanding of the operators' work. The tests would also have been performed with employees at FMV but was not possible due to traveling restrictions caused by COVID-19.

#### 5.4.2 Interview Results

The interviews in this study were semi-structured to allow asking open questions that were not included in the interview guide. This structure allowed flexibility in all interviews, which was useful at F17 since the interviews were not booked beforehand. Many of the interviews were performed in groups of 2-3 people. This might have affected the answers and reasoning among the participants. Phone interviews were held with FMV due to travelling restrictions and this could also have affected the result. All interviews and tests were conducted in Swedish. Therefore, the notes and transcriptions were written in Swedish. The results were translated to English, which might be a source of error. However, the result from all interviews were confirmed with the participants from the interviews which lower the likelihood of errors and misinterpretations.

#### 5.4.3 Prototype-Tests Results

Some prototype-tests were performed with only one interviewer. This may be a source of error since the one leading the interview also was taking notes during the test. There is a chance that information was left out on seven of the interaction-guide-tests and one of the paper-prototype-tests due to this. One question on the interaction-guide-test lacked notes from two participants. This data was excluded in the result since the interaction guide must primarily be compatible with the PK and the slider needs to have the same thickness, since the plastic sheet holds both. Therefore, no further testing was made to complement the missing data.

Three participants preferred multiple thicknesses on the interaction guides. To avoid having multiple answers to questions, the participant could have been asked to rank the different thicknesses from most preferred to least preferred.

### 5.5 UN Sustainable Development Goals

HKP 14 is a transport solution even though it is not made for commercial use. Regarding the United Nations' sustainable development goal 9.4 [23], organizations should invest sustainably in infrastructure. For example, by utilizing resources efficiently, introducing environmental-friendly techniques and industry processes.

If one programmable key were to break, the entire PK panel would have to be replaced. Introducing a touch screen might reduce maintenance, which is considered

complex today by Saab. A software solution can provide the option to update and change the user interface without replacing physical components. This could minimize the use of material and contribute to positive effects on the climate, which is connected to the sustainable development goal 12.5 [24]. However, a tablet probably has a shorter life cycle and if any component were to break, the entire device might have to be replaced.

The suggested interaction guide should, with regards to sustainability, not be used as a disposable product. The interaction guides that were tested in this study were made of PET (0,5-2 mm) and acrylic (3 mm). Referring to goal 12.2 [24], careful attention to material selection of the interaction guide can lower the impact on climate change. Therefore, fossil free plastics, glass, and recyclable materials should be considered. Ensuring responsible use of materials will contribute to a sustainable use of resources [24]. However, it is important that material properties match product requirements. Domestic production should also be considered. In general, the transition to a digital solution could encourage Saab to implement more methods and guidelines for sustainability, which are in line with goal 12.6 [24].

### 5.6 Future Work

In future work, further testing and more attention to details could be examined. Tests with interaction guides and GUI prototypes are recommended to be conducted with operators. It can also be useful to connect a tablet to the MTD and perform time tests with interaction guides that have different thickness to compare with tests that are performed without any guide. Another idea for future work would be to add facets around the cut-outs in the interaction guide, as the current PK have, to potentially improve the usability. Material selection and production methods of an interaction guide could also be further investigated with regards to sustainability. The tablets life cycle should also be considered with regards to this. Lastly, haptic touch screens and the need for executing tasks through hand gestures can be further explored.

## 6. CONCLUSION

The key insights from this case study are summarized below and refer to implementing a tablet with a touch screen in HKP 14.

- The benefits with having a touch screen is that the Programmable Keys (PK) can be customized. The keys and other parts of the interface can be arranged after the users' preferences. However, a consistent base layout is recommended for recognition. A touch screen can provide more keys and functions than the current system e.g. viewing documents, status information or be used for taking notes on. It also allows more frequent updates. The PK functions are appreciated by operators today and will probably be used even more if the interface becomes more user-friendly.
- The drawbacks with touch screens are that they lack tactile feedback. This feedback is important for operators to be able to use the PK without having to look at the interface. Other types of feedback have to compensate for this, which makes visual feedback important. Vibrating- and sound feedback are other options but are not necessarily optimal in HKP 14.
- Achieving additional value by incorporating new functions on a touch screen becomes a trade off with having tactile feedback. Adding an interaction guide with cut-outs can guide the users' screen interaction and improve physical support even though the operators wear gloves.
- The benefits with having a portable tablet is that it can be used anywhere, e.g. outside the helicopter during planning, maintenance, and evaluation of missions.
- The drawbacks with having a tablet are that it might get dropped or lost. This device can become a confidential unit and would probably have to be treated with caution, which may have an impact on the usability.
- The helicopter environment is considered rather stable. Turbulence can occur but it is not common, although the risk of accidental interaction with the PK may increase. In this setting, safety has the highest priority and the future solution should meet this criteria.

Evidently, usage of touch screens has both benefits and drawbacks. The study has shown that touch technology may be a potential solution in HKP 14, as long as the users' opinions and the contextual environment are taken into account in the development.

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## APPENDIX I – ABBREVIATIONS AND TERMINOLOGY

The following appendix provides descriptions of abbreviations and terminology used.

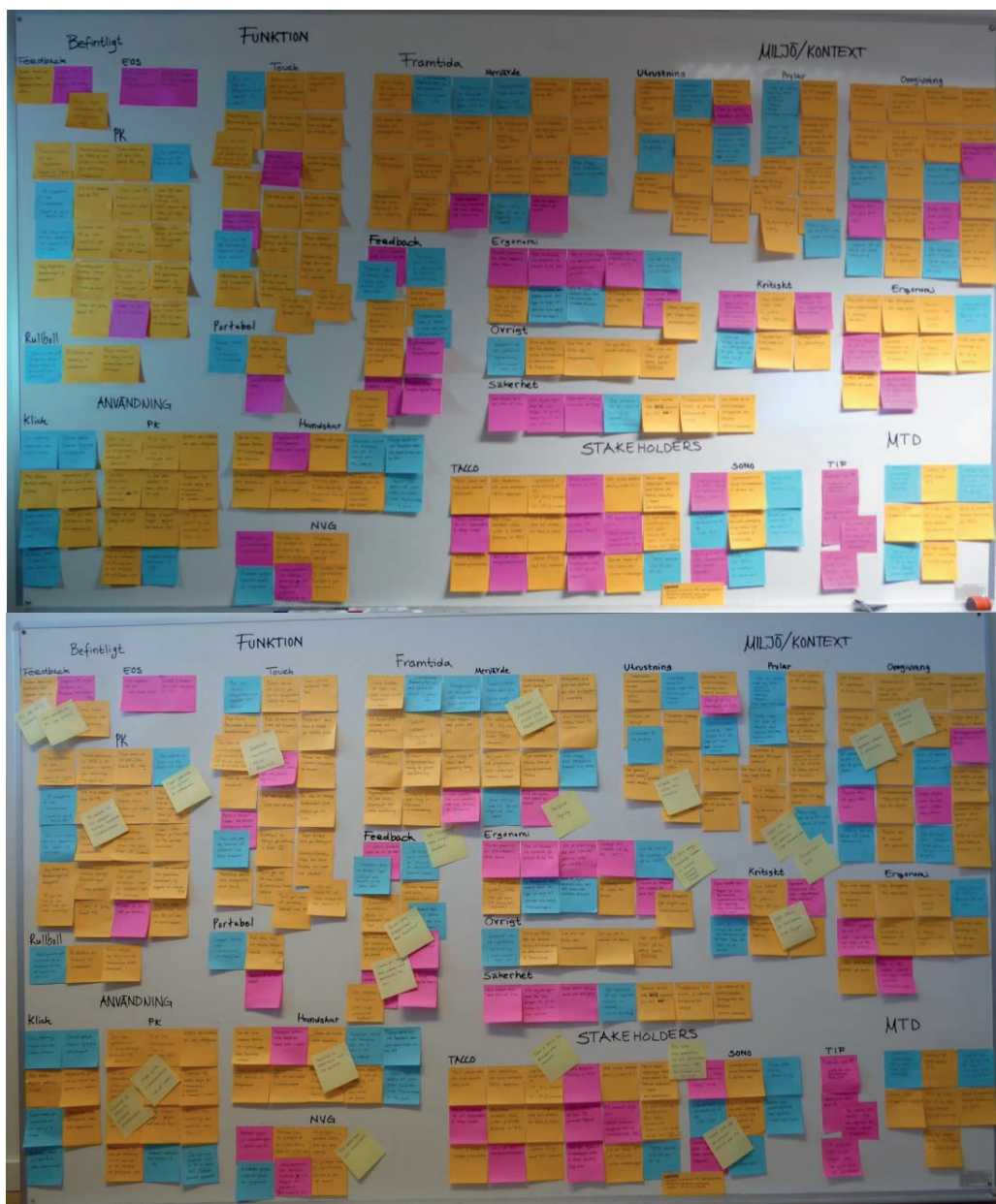
Abbreviation	Description
ASW	Anti Submarine Warfare
DOD	Department of Defense
EMC	Electromagnetic Compatibility
EFB	Electronic Flight Bag
FMV	the Swedish Defense Materiel Administration
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HKP 14	Helicopter 14
HMI	Human-Machine Interface
NVIS	Night Vision Imaging Systems
NVG	Night Vision Goggles
MFC	Multi Function Console
MMS	Mission Management System
MTD	Main Tactical Display
PK	Programmable Keys
SENSO	Sonar operator
TACCO	Tactical Coordinator
TID	Touch Indicated Display
TIF	Technician in Flight
TMS	Tactical Mission System

Terminology	Description
Key	Buttons on the PK are referred to as keys
Tablet	A portable computer device with a touch screen
Touch screen	Computer display with an interactive interface



## APPENDIX II – AFFINITY MAPPING

The result from F17 in Ronneby was clustered in two steps and this appendix provides images of this process. Initially, the respondent's opinions, thoughts, and needs were written down on post-its. The post-its were color coded where orange are the TACCOs, blue is the SENSO, and pink is the TIF. In the first round, the post-its were clustered into: Requests, Function, Usage, Environment/Context, Role/Task, Risks, and MTD. The second round they were re-clustered into main areas as well as subareas: Existing function (Feedback, Camera, PK, Trackball), Future function (Touch, Portable, Value-adding, Feedback, Ergonomics, Safety, Other), Usage (Interaction, PK, Gloves, and NVG), Environment/Context (Uniform, Belongings, Critical, Ergonomics), User Stakeholders (TACCO, SENSO, TIF), and MTD. After this, the key insights were identified and placed on the cluster with yellow post-its.





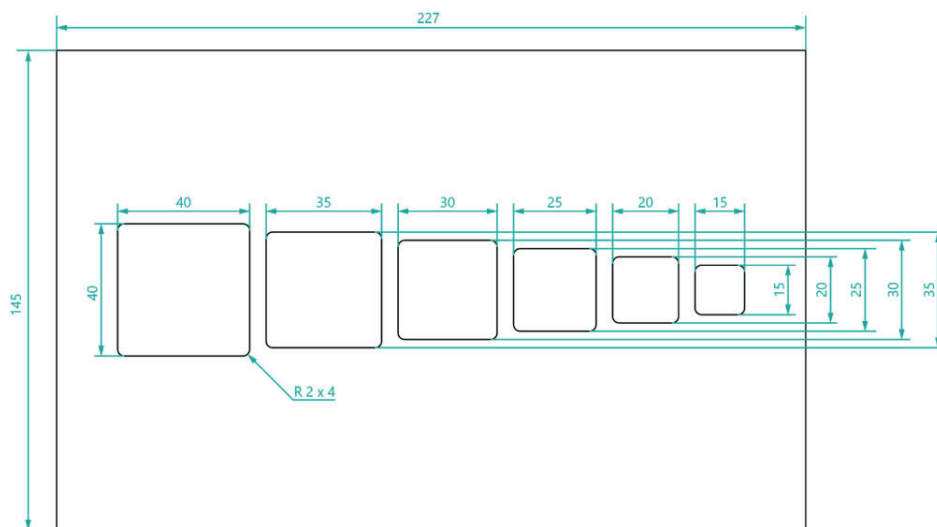
## APPENDIX III – INTERACTION GUIDE, TESTING PROCEDURE

### Equipment Used in the Test

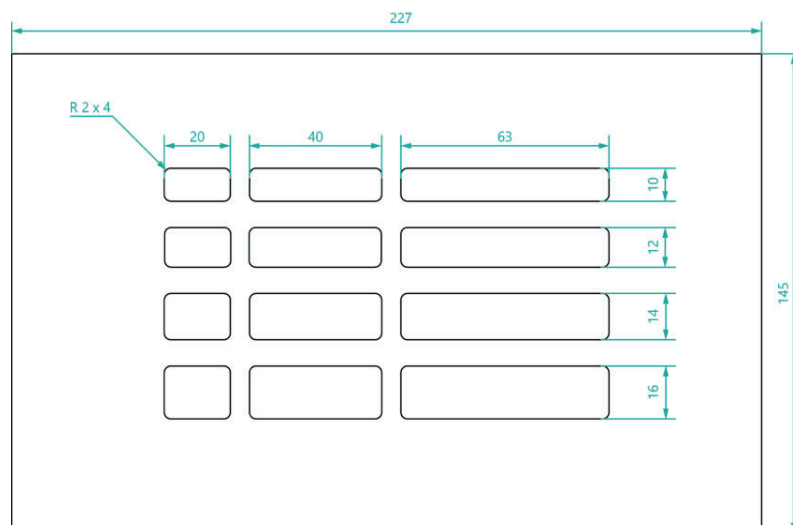
One MilDef DS11 tablet, two gloves made of goat leather in size 8 and 9, four different interaction guides with thickness 0.5, 1, 2, and 3 mm, one interview guide.

### Testing Procedure

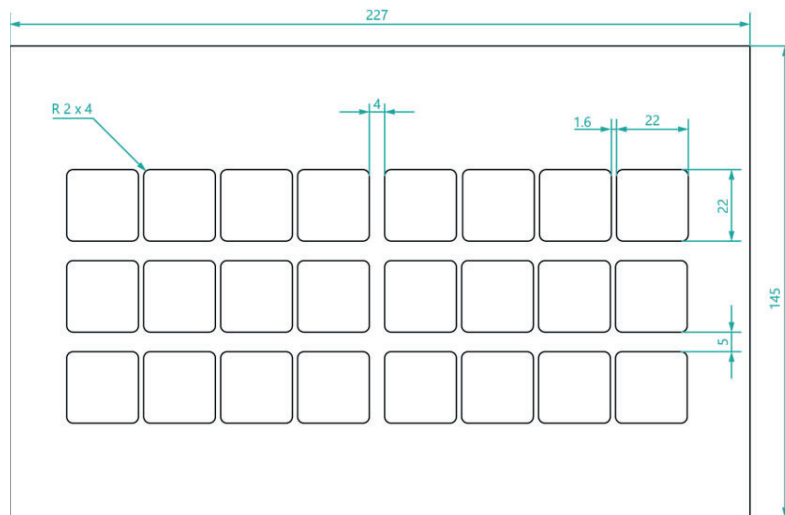
1. An interaction guide with cut-outs for different key sizes was placed on the tablet. First, an interaction guide with a 3 mm thickness was tested. The test participant sensed the guide with and without gloves. The procedure was repeated for the same guide with thickness 2, 1, and 0.5 mm.



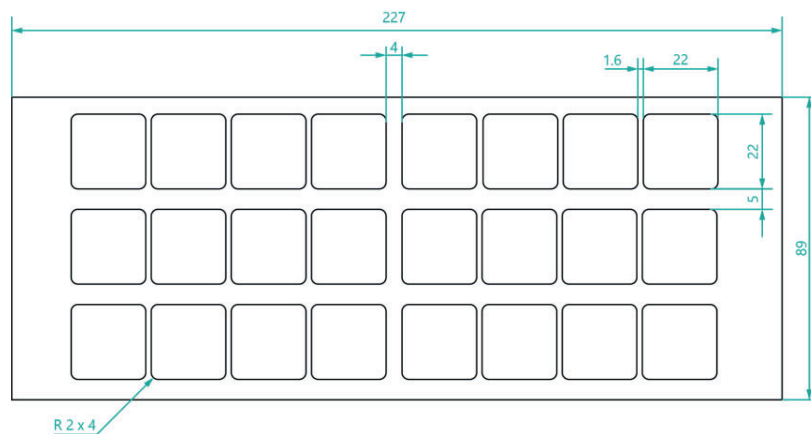
2. An interaction guide with cut-outs for different sliders was placed on the tablet. First, an interaction guide with a 3 mm thickness was tested. The test participant sensed the guide with and without gloves. The procedure was repeated for the same guide with thickness 2, 1, and 0.5 mm.



3. An interaction guide with cut-outs to fit a prototype with an interactive interface, provided by Saab, was placed on the tablet. First, an interaction guide with a 3 mm thickness was tested. The test participant sensed the guide with and without gloves. The procedure was repeated for the same guide with thickness 2, 1, and 0.5 mm.



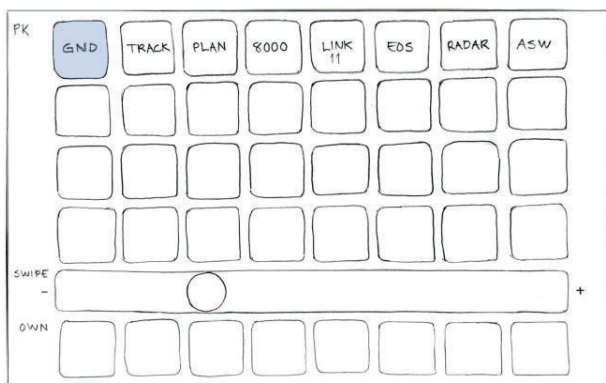
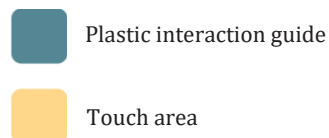
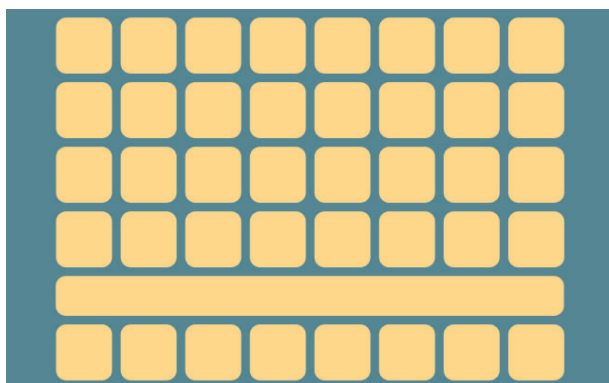
4. A smaller version of the interaction guide was created to allow free space above and below the guide. The interaction guide had cut-outs to fit a prototype with an interactive interface, provided by Saab, and was placed on the tablet. First, an interaction guide with a 3 mm thickness was tested. The test participant sensed the guide with and without gloves. The procedure was repeated for the same guide with thickness 2, 1, and 0.5 mm.



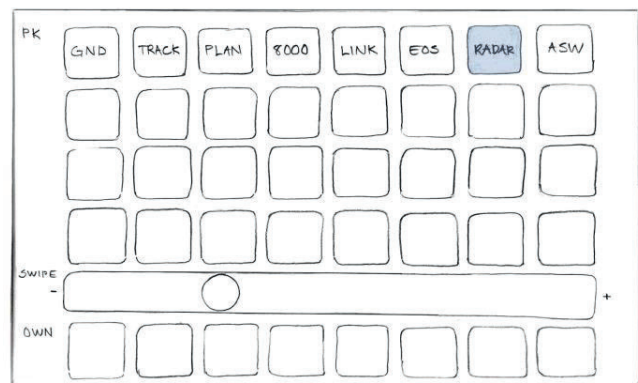
## APPENDIX IV – PAPER-PROTOTYPE-TEST

This appendix provides figures and descriptions of the test procedure used in the paper-prototype-test. One prototype was shown at a time and the participants were asked to select certain functions to resemble the touch interaction. The paper-prototypes were placed in a frame made of cardboard to represent a tablet during the test, see figure 4 in section 3.5. After each prototype sequence, the participants were able to give feedback on the GUI. The feedback from the test is summarized in the end of this appendix.

### Paper-Prototype 1: Full-Covering Interaction Guide



1. This view displays the original PK. A slider and a row with 8 favorite keys are added. Now press RADAR.

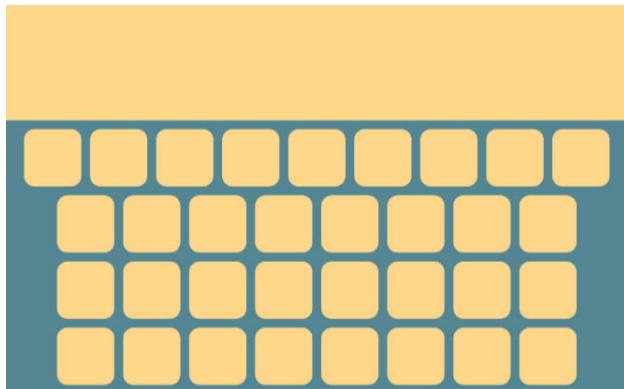


2. The functions for RADAR will appear. Now press a key of your choice.



3. When pressing a key that has a direct impact on the system, a confirmation step appears as a safety feature. Now press NO to deactivate the function.

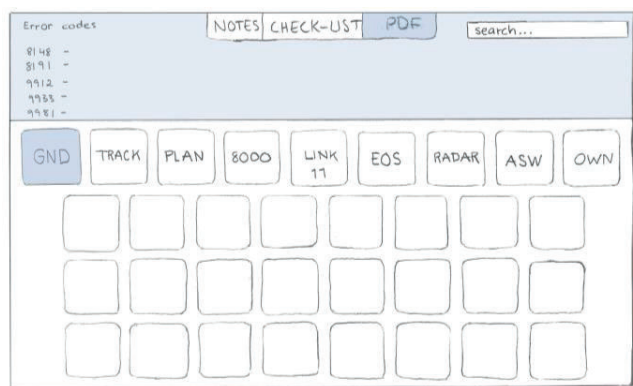
## Paper-Prototype 2: Semi-Covering Interaction Guide



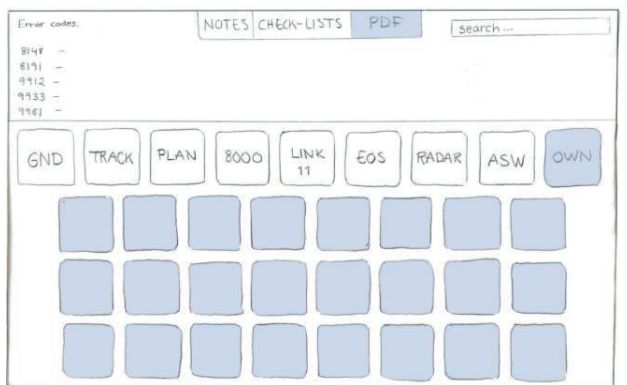
- Plastic interaction guide
- Touch area



1. This view displays the original PK and NOTES are displayed on the top. Now press PDF.





2. A PDF is displayed at the top. In this view, it is possible to search in the PDF and read it. Now press OWN.

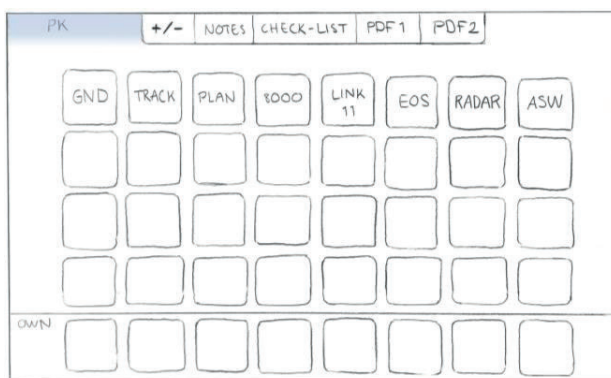


3. The key OWN allow 24 favorite keys to be saved.

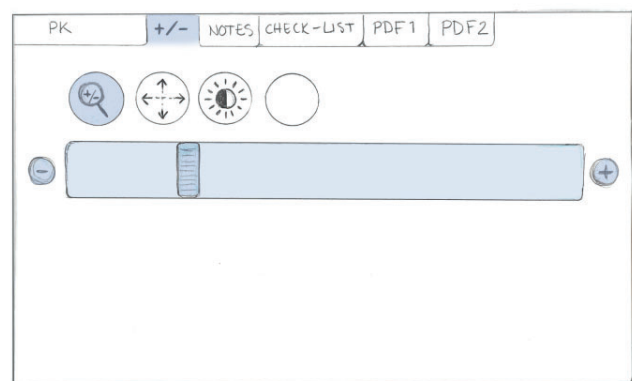
### Paper-Prototype 3: No Interaction Guide



-  Plastic interaction guide
-  Touch area



1. This view displays the original PK. An additional row is added where 8 favorite keys can be saved. Now press the tab +/-.



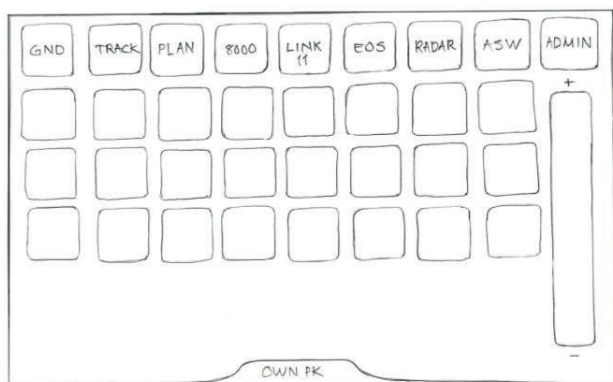
2. In this tab, a slider is displayed to adjust different values. For example, zoom in/out, map scale or brightness on the tablet. Press PK to return to return to view 1.

## Paper-Prototype 4: No Interaction Guide

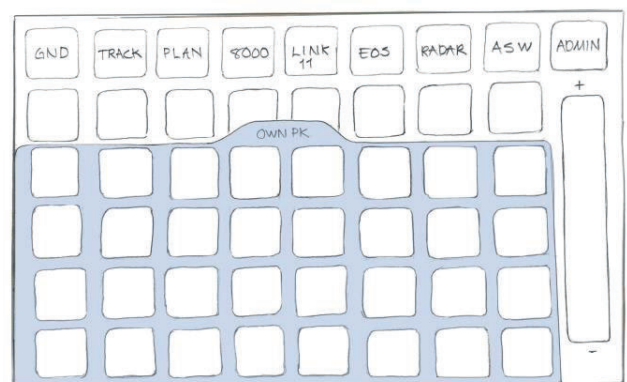


 Plastic interaction guide

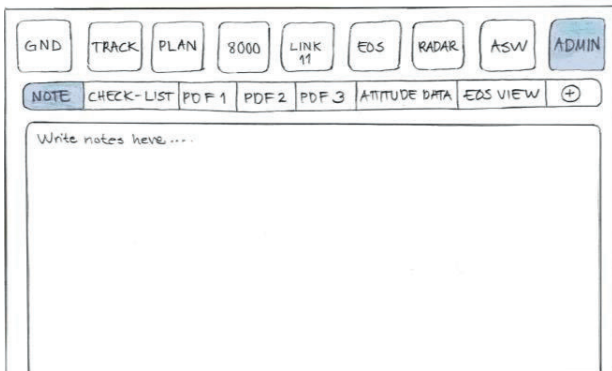
 Touch area



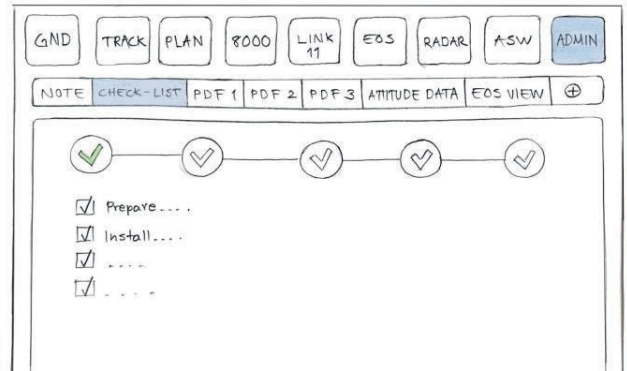
1. This view displays the original PK. An ADMIN key is added at the upper right corner. The tab OWN PK is placed at the bottom. Now press OWN PK.



2. In this view OWN PK are displayed, where 32 favorite keys can be saved. Now press ADMIN.



3. NOTE is activated. In this view notes can be written by hand or with the existing keyboard. Now press CHECK-LIST.



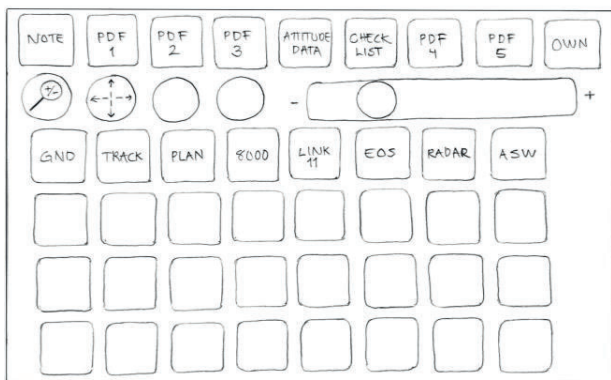
4. CHECK-LIST is activated. In this interactive checklist, specific preparing tasks can be checked before takeoff for example. Now press any of the PK to return to the first view.

## Paper-Prototype 5: No Interaction Guide

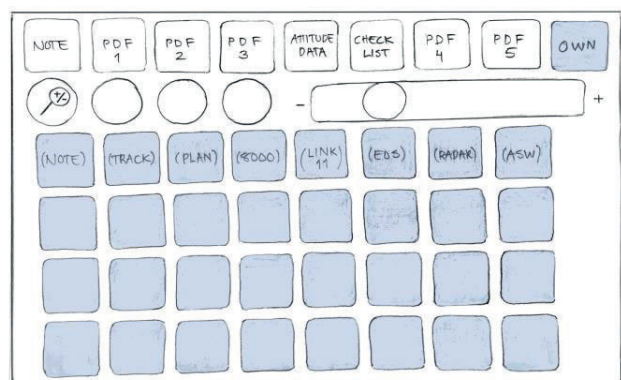


 Plastic interaction guide

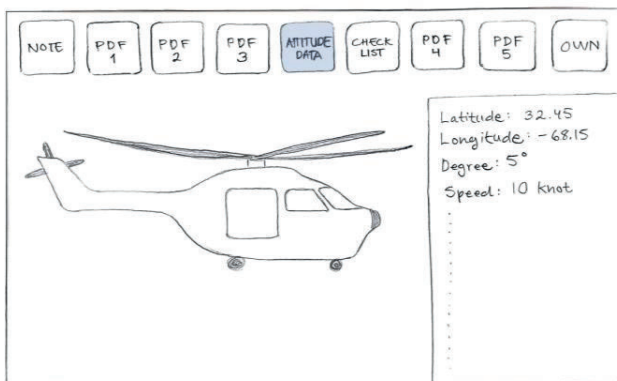
 Touch area



1. This view displays the original PK. Notes, PDFs, OWN etc. are placed at the top row and a slider is added. Now press OWN.



2. In this view, the key OWN is displayed, where 32 favorite keys can be saved. Now press ATTITUDE DATA.



3. ATTITUDE DATA is activated. In this view, flight navigation data is displayed. Press ATTITUDE DATA again to return to the PK view.

### **Feedback from the Paper-Prototype-Tests**

The feedback from the paper-prototype-tests are summarized below for each paper-prototype.

#### **Feedback on Paper-Prototype 1**

One participant commented that the layout looked consistent since all keys have the same shape, which was considered a good thing. Another respondent mentioned that the key size was good. The same participant also suggested adding arrows or toggle keys to enable the user to browse for more functions under each menu key. Another participant wanted a more clear indication of which keys that belong to which menu. One participant said that the slider is taking up relatively large space on the interface so it is important to investigate how much the operators will use it. Another one said that a longer slider provides better precision when targeting a specific value.

Two participants thought it was good to use the cut-outs in the interaction guide to view and confirm the confirmation step. One participant wanted to see which key that was pressed when the confirmation step showed up, to be able to verify that the right or wrong function was actuated. Three participants thought it was a good idea to add a confirmation step before deleting anything on the screen. One of them mentioned that a confirmation step is unwanted for actions that have to be performed quickly with the PK. Another respondent agreed on this and thought it would take more time. Additionally, one person said that it should only be used for safety critical functions, which are not available on the PK today.

#### **Feedback on Paper-Prototype 2**

One participant thought that the semi-covering guide works best if it is placed on the lower half of the screen. Four participants thought that the free touch area might be too small to write on with the fingers and five thought it was too small to view PDFs. However, one of them said that the area was sufficient to scroll in documents. The possibility to take a screenshot of a map or a camera view and then draw on top of it was a suggested function by one participant. Another one thought it might be better to use the tablet to draw on and write text with the existing keyboard. Taking notes on the free touch area on the tablet was considered useful by one participant. Having the keyboard connected to the tablet was considered beneficial by two participants. One participant thought that the free touch area might be too small when executing the new functions.

Four participants suggested hiding the PK to view PDFs in fullscreen, even though it has an interaction guide. Another one suggested hiding the PK when selecting the search bar in the PDF-tab. One of them wanted arrows for scrolling in PDFs since the interaction guide might limit hand gestures. One participant mentioned that the guide might have an optical impact when reading text behind it and realized that this might not be preferred. Another participant highlighted that the argument for reading behind the guide fails if the plastic gets scratched since it lowers the readability. This person also mentioned that if the height and the width of the free area is not large enough, the information could potentially be displayed on the MTD. A solution for selecting documents was considered missing by one participant since there might be several PDFs, notes and checklists.

One participant pointed out that a slider is not included here and could be added as a tab since it might not be used that often. It was suggested that the slider would appear when pressing keys such as "ZOOM +". The slider could potentially be displayed on top of the PDF, according to the same participant. Another one thought it was good to center the first row of the PK on the GUI.

The key called OWN was considered useful by two respondents. One of them said that the key OWN was easy to distinguish and preferred the way it was presented in this GUI. However, another participant highlighted that this concept requires one extra actuation to access OWN PK. This participant said that the number of keys saved to the key called OWN has to be evaluated with operators. An "edit mode" was necessary to add according to one participant to customize the arrangement of the PK.

Three participants suggested the guide to be removable when using the tablet outside the HKP 14, e.g. when viewing the helicopter manual. Two of them wanted to have a software-based keyboard. Another respondent stressed that the

interaction guide has to be stored somewhere if it is removeable. Additionally, a FASS application for medical missions might be a wanted application in the future since Wi-Fi connection could be available outside the helicopter, according to the same respondent.

### **Feedback on Paper-Prototype 3**

One participant liked having the slider on a separate tab without an interaction guide. Another participant suggested to investigate how often a slider function will be needed. The same participant also considered having more than one slider, but came to the conclusion that one is better because of the limited space on the interface. Another idea the participant had was to connect the slider function to the physical keyboard to enable adjustments in two ways. The same respondent appreciated the round keys connected to the slider function since the shape differentiates them from the other keys. The participant also wanted to add a numerical value on the slider for indication of the adjustment. The slider was suggested to be used for adjusting map intensity settings. Two participants also mentioned that more keys will be needed above the slider to adjust more settings. The idea of indicating a key selection with color, was appreciated by one. However, one respondent thought it was difficult to understand the sliders functionality.

### **Feedback on Paper-Prototype 4**

One participant mentioned that the tab called OWN PK felt like something you wanted to do quickly. It was not considered good that the tab, OWN PK, would close if touching the area outside the tab by mistake. One participant liked having the OWN PK as a tab since the space was utilized well and the color indication was clear. The same participant also suggested using this type of tab for more functions. In contrast, two participants preferred to have the OWN function as a key rather than a tab since it was considered quicker and better. The tab was also considered too small to touch when actuating the function according to one of them. Another one suggested fading the PK behind the tab OWN PK to make it easier to see the PK menus. One participant pointed out that it is inefficient to press OWN PK again to close it. Having two fixed rows of OWN PK would be an option to have them visible all the time but having too many keys might be confusing. Another participant disliked that OWN PK were placed over the slider in this GUI.

Having the guide removable was considered troublesome by one participant since the layout of the GUI needs to be consistent. The same participant suggested using more information on the tablet to make the situation picture on the MTD clearer. Another participant pointed out the possibility to create a customized layout for each operator. The vertical slider was preferred by one participant since the hand motion became smaller compared to using a horizontal slider. Another participant mentioned that a long slider allows precise adjustments and that an indication of what value the slider represents is needed.

One participant was unsure how the operators use checklists but mentioned that the helicopter crew check the TMS status before takeoff, which could potentially be implemented in the future system. Three participants liked the way the checklist was presented, one said that several checklists were preferred and the other two suggested having them as a PDF library. Tabs were not a preferred option for having several checklists, according to one. The same respondent suggested notes to be included in the PDF library and said that the writing becomes big when drawing with fingers. Uploading own notes to the tablet before a mission was suggested by another participant. Another participant preferred the tabs instead of the key called ADMIN where all the extra functions are collected. Meanwhile the two participants thought that the ADMIN key was good.

### **Feedback on Paper-Prototype 5**

One participant expressed that the keys and other functions were large enough but that it was too much information displayed at once, which indicated clutter. This person preferred an ADMIN key where access to PDFs, notes etc. are collected since it makes the GUI look clear. One participant thought this GUI had too little space for the slider, while another participant thought this could be solved by adding a toggle function. One respondent said that the slider bar is good to use in combination with the MTD screen but wanted it to be compatible with both x- and y- direction. According to another one, the slider is differentiating the PK from the extra functions on the first row, which was considered positive. Combining the text on the PK with symbols was mentioned as a good thing but it was considered better to skip the icons if they are irrelevant.

One participant mentioned that the functions on the first row might not be enough to include all wanted functions, which is a limitation. Another one said that it is unknown how often the functions on the first row will be used and they might lock up space for other keys. Also, one respondent mentioned that it should be possible to exit a function by pressing it again or by pressing an exit function. The exit function two other respondents agreed on. Combining both ways should be avoided, according to one of them.

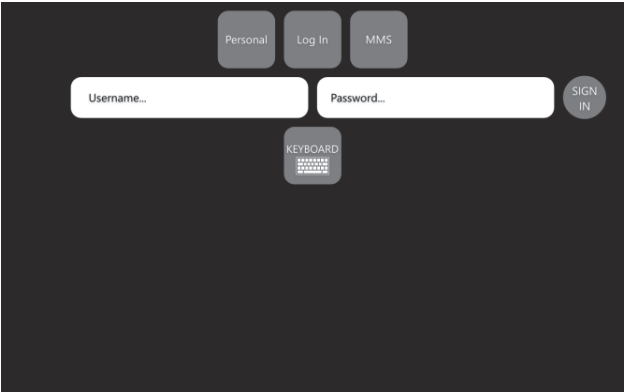
One participant wanted the OWN key to be colored to make it stand out and liked that it was placed on the first row. It was preferred to have the OWN function as a key and not as a tab, according to another one. However, one participant was unsure if the login function would be used by operators since a variety of options often result in a base layout that is easier to use.

### **General Feedback on the Paper-Prototypes**

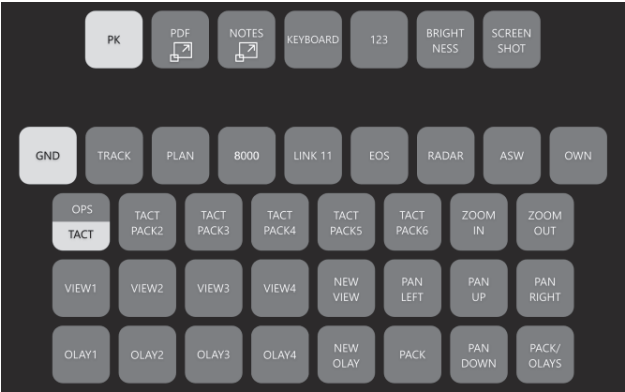
Two participants expressed that the interaction guide is a good idea. However, one of them thought it is more useful in the beginning, when the GUI is new, but that operators will remove it later since it can be annoying. The same person said that it would be a benefit if the interaction guide was removable since it would allow increased usability. It was also suggested to change personal settings via a computer, when preparing a mission, instead of having individual logins on the tablet. Two participants discussed potential materials for the guide. Lexan plastic was suggested since it is durable. Glass can also be used in similar with the protection for mobile phones.

APPENDIX V – FULL-COVERING INTERACTION GUIDE

Below, the GUI concept of the Full-covering interaction guide is presented in a sequence. By selecting certain functions, different views are displayed.



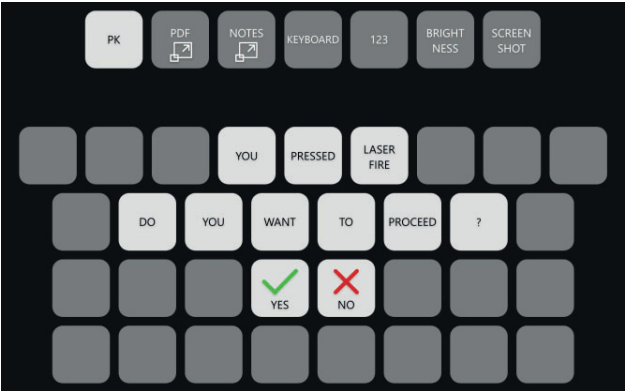
1. Press SIGN IN.



2. In this view the PK are displayed. Now press OWN.



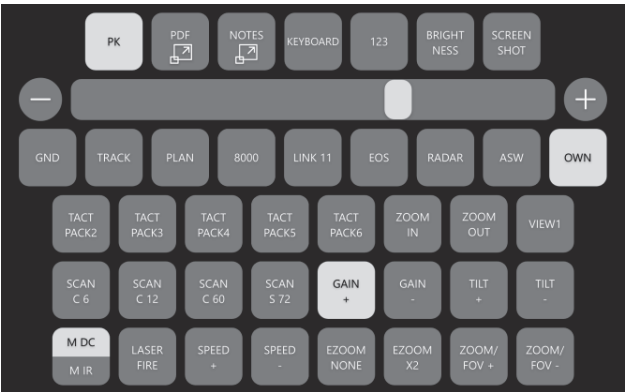
3. In this view favorite keys are displayed. Now press LASER FIRE.



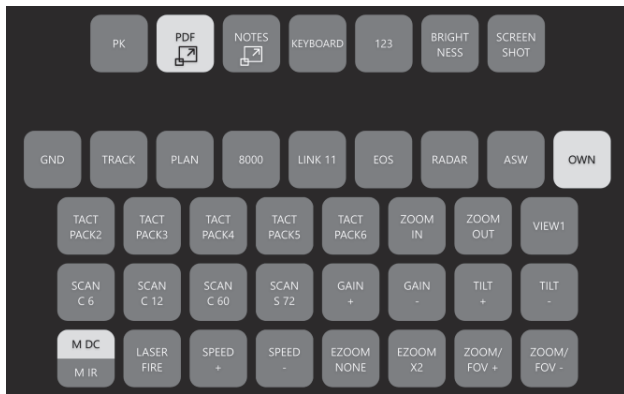
4. A confirmation step appears. Now press NO to deactivate.



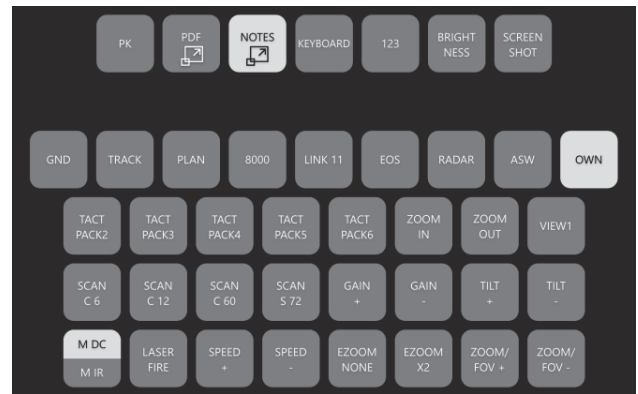
5. LASER FIRE is deactivated. Now press GAIN +.



6. GAIN + is activated and the slider appears to adjust it. Now press PDF.



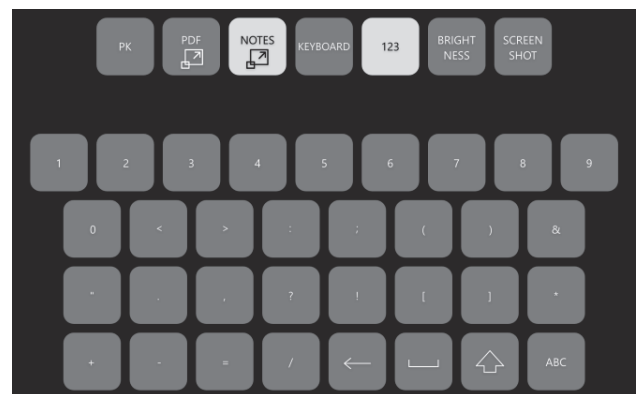
**7. A PDF library is displayed on the MTD. Now press NOTES.**



**8. Notes are displayed on the MTD. Now press KEYBOARD.**



**9. A touch keyboard is displayed. Now press 123.**



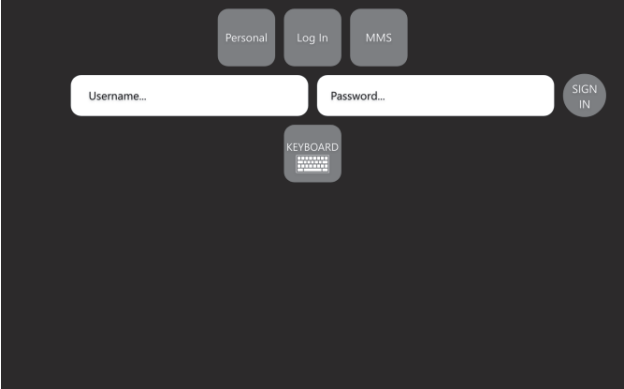
**10. Numbers are displayed. Now press BRIGHTNESS.**



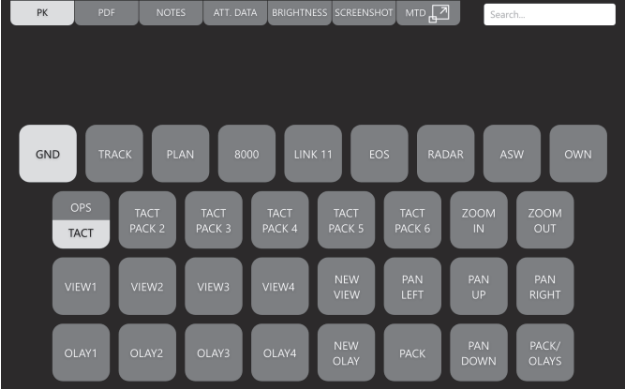
**11. BRIGHTNESS is activated and the slider appears to adjust it. Now press PK to return to view 2.**

**APPENDIX VI – SEMI-COVERING INTERACTION GUIDE**

Below, the GUI concept of the Semi-covering interaction guide is presented in a sequence. By selecting certain functions, different views are displayed.



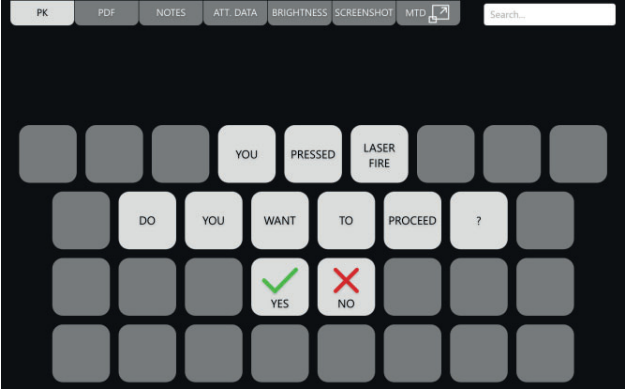
**1. Press SIGN IN.**



**2. In this view PK are displayed. Now press OWN.**



**3. In this view favorite keys are displayed. Now press LASER FIRE.**



**4. A confirmation step appears. Now press NO to deactivate.**



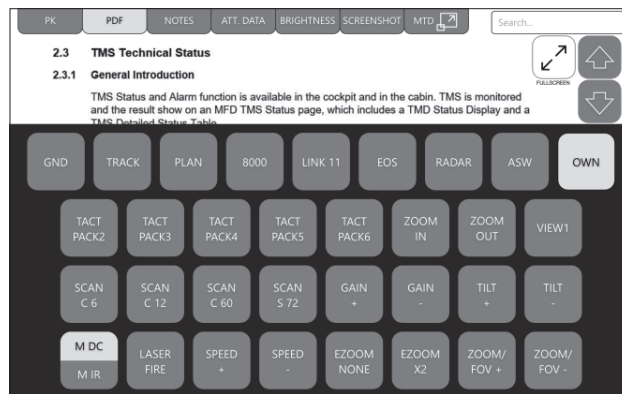
**5. LASER FIRE is deactivated. Now press GAIN +.**



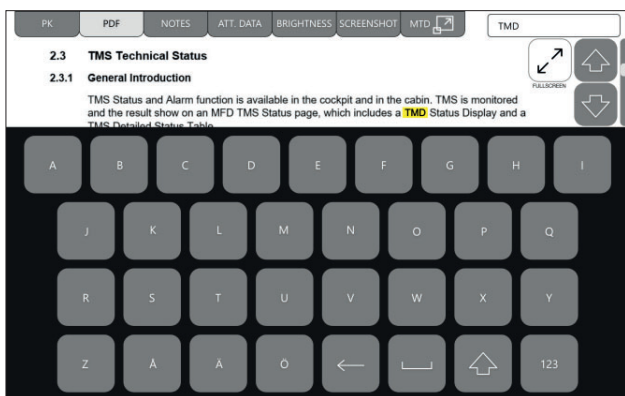
**6. GAIN + is activated and the slider appears to adjust it. Now press PDF.**



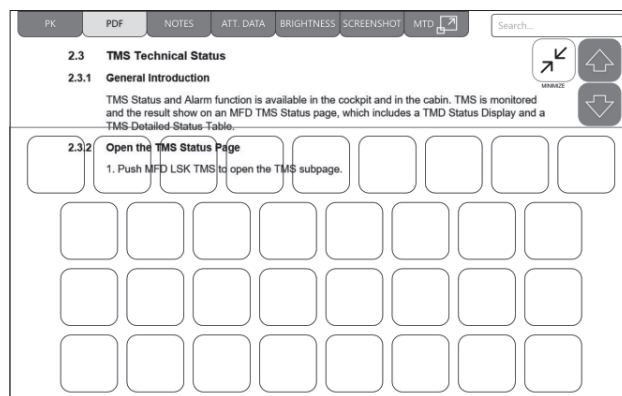
7. A PDF library is displayed on the top. A PDF is selected from the folders.



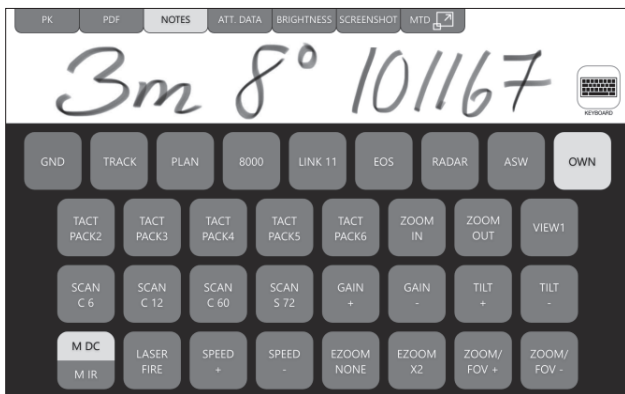
8. A PDF is displayed in this view. Now press the search bar.



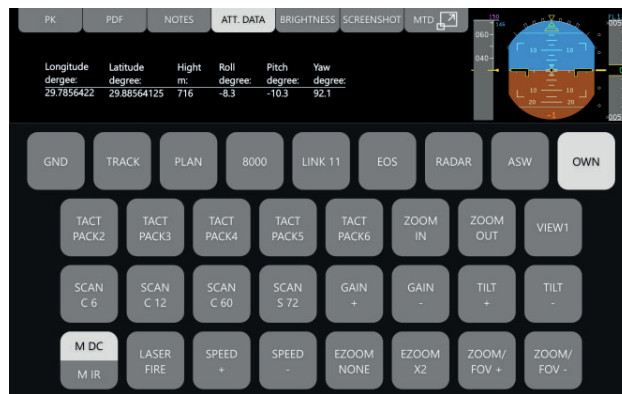
9. The search function is activated. Now press FULLSCREEN.



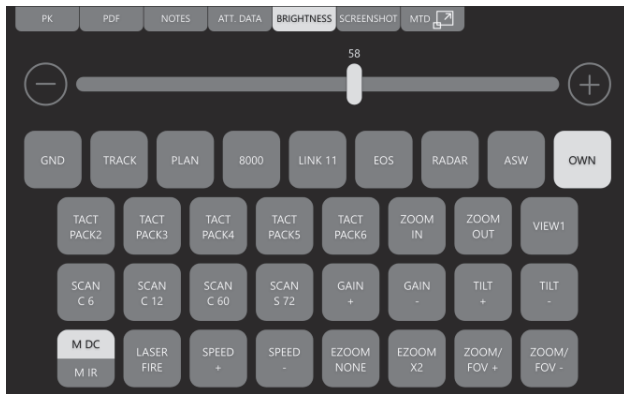
10. The fullscreen is displayed. Now press NOTES.



11. Notes are displayed. Now press ATT.DATA.



12. The attitude data is displayed. Now press BRIGHTNESS.

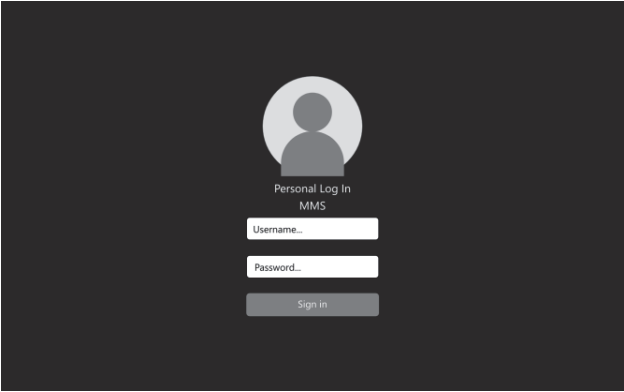


**13. BRIGHTNESS is activated and the slider appears to adjust it. Now press PK to return to view 2.**

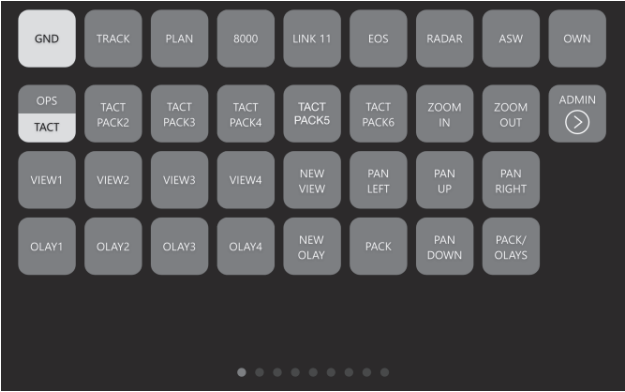


APPENDIX VII – NO INTERACTION GUIDE

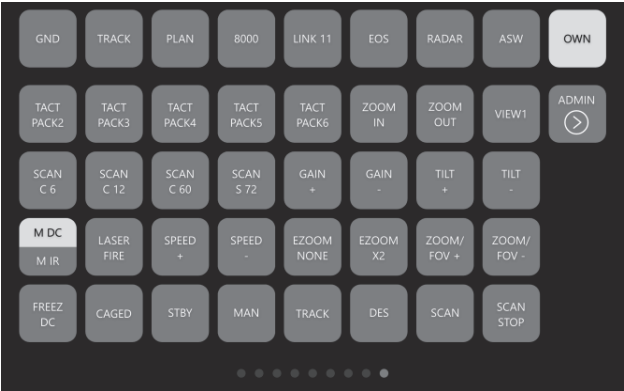
Below, the GUI concept of the No interaction guide is presented in a sequence. By selecting certain functions, different views are displayed.



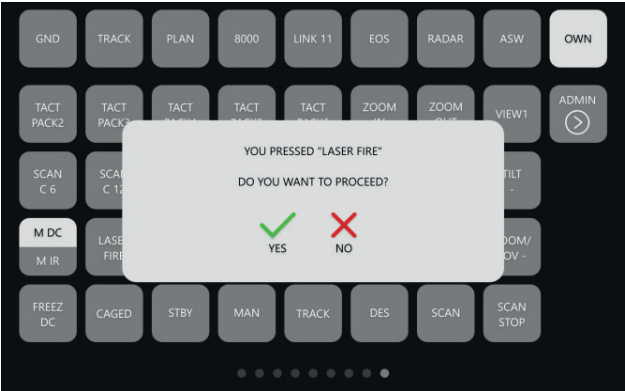
1. Press SIGN IN.



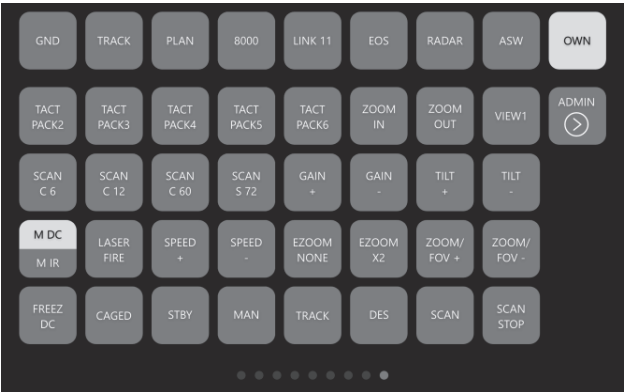
2. In this view PK are displayed. Now press OWN.



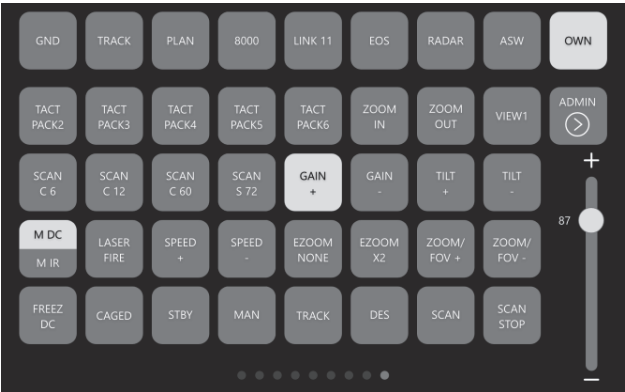
3. In this view favorite keys are displayed. Now press LASER FIRE.



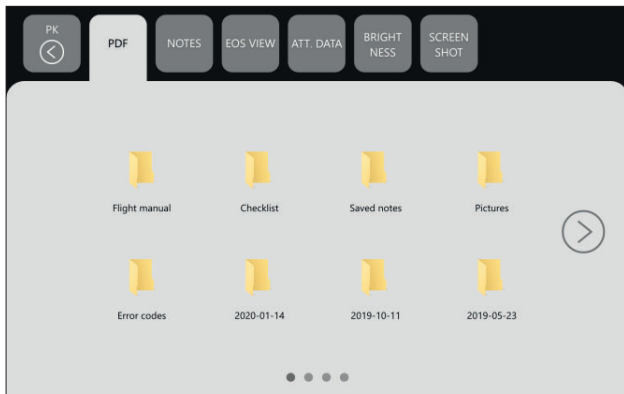
4. A confirmation step appears. Now press NO to deactivate.



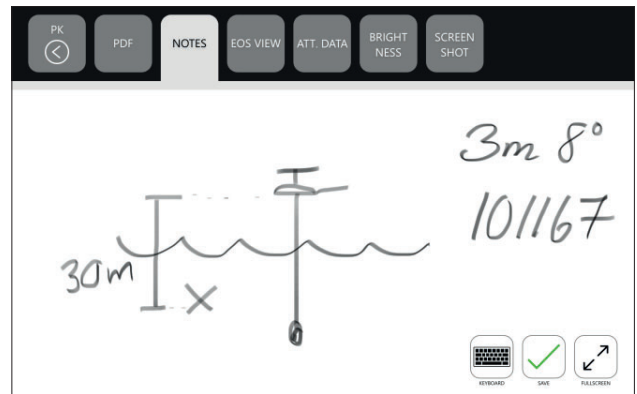
5. LASER FIRE is deactivated. Now press GAIN +.



6. GAIN + is activated and the slider appears to adjust it. Now press PDF.



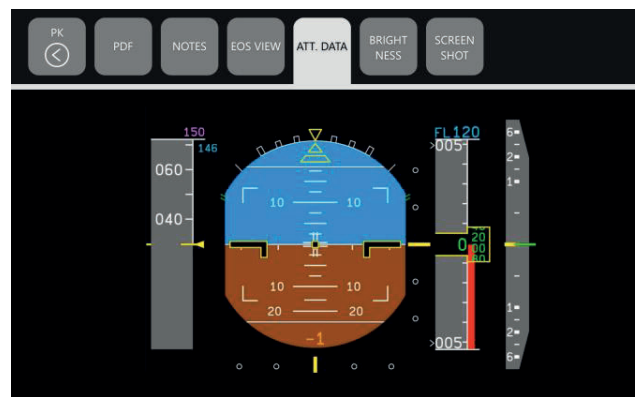
7. A PDF library is displayed. Now press NOTES. Press NOTES



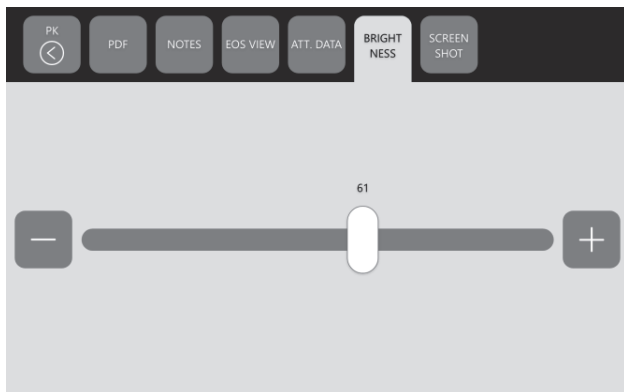
8. Notes are displayed. Now press EOS VIEW.



9. The EOS VIEW is displayed. Now press ATT.DATA.



10. The attitude data is displayed. Now press BRIGHTNESS.



11. BRIGHTNESS is activated, and the slider appears to adjust it. Now press PK to return to view 2.



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