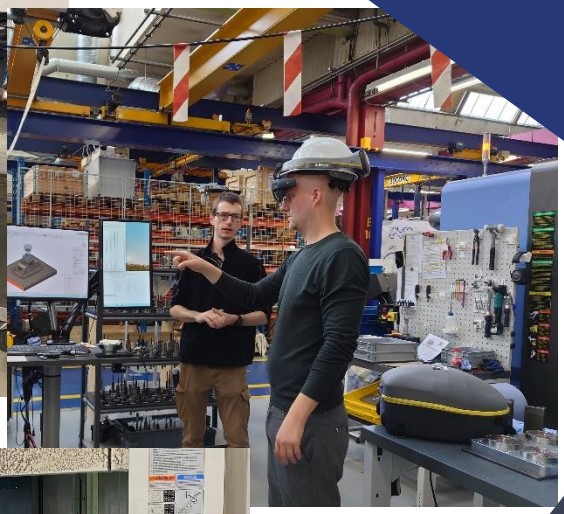
REMOTE PROCESS OPTIMIZATION



DAMRC

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1 Executive Summary

The idea of the project is to explore the possibilities to guide industrial companies preforming a Tap Test on their own CNC machines remotely by using the Microsoft HoloLens and the technology augmented reality. This way an expert from DAMRC will guide and assist an operator to do the TapTest without requiring the physical presence of the expert from DAMRC. The following project focuses on the combination of Microsoft HoloLens remote assistance and TapTest. For this, two internal usability tests have been conducted involving employees familiar with the equipment and other three external test companies with individuals that are unfamiliar with the technology and with DAMRC present during the test as well as a test with DAMRC not being present at the company but giving remote assistance. The results of the three company tests have to some extent been successful in the combination of both technologies. Companies taking part in the project showed accuracy and efficiency when following the instructions provided through the remote assistance when the test are fresh in mind. But also, many challenges such as, technical issues or user training needs to be further addressed, although the combination of both technologies has promising potential.

We discovered that the use of the Microsoft HoloLens has a limit of the time as the technicians are experiencing sickness – we also learned that when untrained having to focus on two new equipments – Taptest and the Hololens – was too much of a challenge.

A company also commented that the Hololens might be exchanged with today's other possibilities of video, phonecameras or teamsmeeting ect. Thus, the technicians may use technology familiar for the video transmission instead of having to deal with two new technologies.

However, the Microsoft Hololens may be used for Remote Optimization in other connections than just the Taptesting.

By requiring the 64-bit Taptest system, DAMRC has been able to support many companies for optimization that was not the possibility earlier.

2 Introduction

With the emergence of new technologies – namely Mixed Reality (MR) technologies – new possibilities arrive. With this project, DAMRC seeks to explore the possibility for deploying and testing if advanced Augmented Reality (AR) technology can be a media to let untrained operators and technicians use and benefit Advanced Modal Optimization Equipment (TapTest equipment) targeted optimizing machining process parameters.

The idea is to implement an AR headset together with the Advanced Modal Optimization Equipment (Tap test) at industrial companies. Via the AR equipment and related software, the user is quickly trained in assembling and setting up the equipment via AR instructions and guided in how to use it for optimization or/and problem solving. Further, the technology opens for on-demand support from experts to support specific challenges, while eliminating the challenge of geographical positioning and logistics of the experts.

Via this setup, the participating company gains the ability to dispose of the equipment over a longer period – e.g., 20-30 days, to broaden the use of the equipment, and in a more natural way bring its uses into daily problem solving and process optimization.

The goal of the project is to enlighten if this idea is viable, dos and don'ts, and assess the general relevance of MR and AR technologies for similar cases.

3 Project Scope

The project aims to provide insights into the use of remote support on machining challenges for industry through new digital tools (Mixed-reality tool) like HoloLens including an optimization system such as Tap test system (i.e. Metal Max). The idea is to purchase and lend one set of Tap test equipment to machining companies over a period of e.g. 20 days, where DAMRC can provide support to the company from our location in Herning using Mixed reality equipment. The set-up will hopefully provide a more flexible and in-situ option to help companies faster with their challenges.

4 Hypothesis

- Companies will be able to do the Tap test without requiring any expert to go to the companies physically.
- HoloLens will help take the most advantage of TapTest equipment.

5 Success Criteria

The success of this project relies on the realization of TapTest by a non-expert using remote assistance to guide the person. The idea is that operators that have never used TapTest before will be able of Tap testing using the HoloLens guided by an expert if needed.

At least 1 company states that mixed reality can be a part of future remote support by optimizing production.

That the DAMRC builds digital competences to support companies regardless of location

The project will help to shed light on whether, and how, machining challenges can be mitigated when they arise in an environment where communication between technician and specialist is virtual. In addition to the concrete optimizations at the individual machining companies, the ambition of this pre-project is to uncover the potential for implementation of the technology as a communication tool for remote support in the use of equipment for process optimization in Danish industry.

6 Risk Analysis

In order to gain success on the project there are some risks that need to be considered. First, as two new technologies are going to be used it could be overwhelming for the person using them, especially if they are not very skilled with new technologies. Also, internet connection is also a risk to consider as we need a stable connection to make the call for the remote assistance. In the end, the usage of HoloLens can lead to dizziness when used over a period for some people.

7 Literature study

As a first step of the project, existing literature and solutions have been reviewed. The goal of this review has been to gain insight into existing experience and solutions of deploying AR and MR.

7.1 Case examples

Case examples on existing uses of AR/MR technologies have been reviewed in the search of gaining insights on what and how to use the technology, together with remarks on things to consider when prospecting for AR/MR use.

7.1.1 AR & MR for remote assistance

Several cases exist on AR & MR for remote assistance. The general remark on these cases, is that the technology is often used internally in a corporation or as part of the support service that follows a sale, e.g., of a machine, and the reasoning for using the technology is logistics and resource availability of knowledge intensive employees.

7.1.1.1 Volvo & Renault Trucks – using AR for hands-free remote assistance for Automotive Repair & Maintenance

Volvo Group (Volvo & Renault Trucks) were faced with the challenge of geographically dispersed field technicians that needed support from product quality engineers (PQEs) on frequently changing maintenance and repair procedures, or new field technicians which needed training, procedures, and best practices from experienced technicians – procedures and practices which might be undocumented (Volvo, 2018).

As product quality engineers and experienced field technicians are limited and spread across various geographical locations it can be difficult to have the subject matter experts on site for support of maintenance and repairs, why technicians often seek remote assistance via tablets and phones. However, this limits the ability to conduct repairs parallel with the remote assistance, which is why a hands-free remote assistance system was sought.

The Volvo Group selected the RealWear HMT-1 hardware solution, combined with Librestream Onsight Connect software (Figure 1 and Figure 2). A solution which meets their requirements for a system.

Figure 1. Visualizations of RealWear's HMT-1 solution.

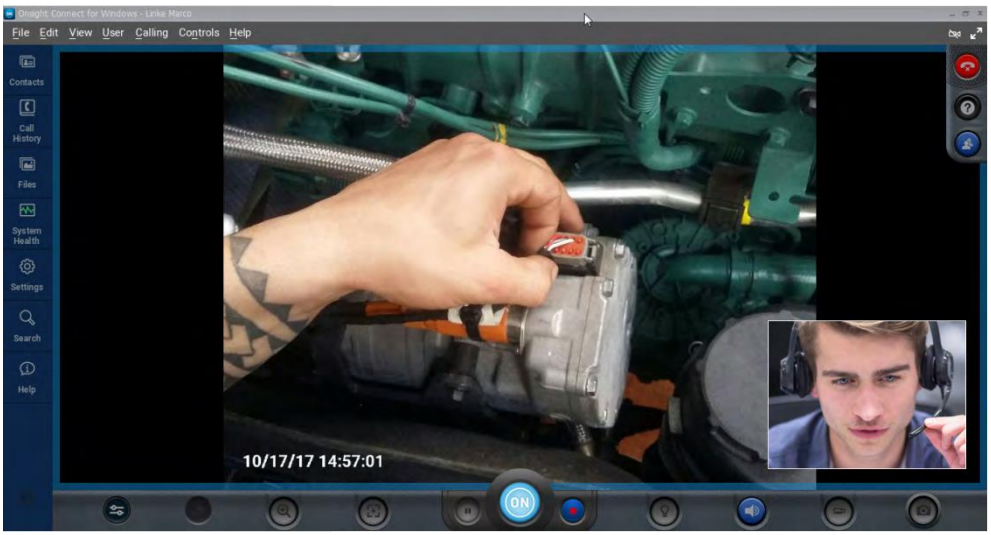

Figure 2. Visualization of Librestreams Onsight Connect software platform for AR (Volvo, 2018).

In their search for the right solution following criteria was set (Anonymous, 2021):

- **Easy to use, deploy, and scale**
- **Hands-free** but secure collaboration, with the ability to take control of the camera remotely
- Expand beyond live video, giving users the option to **take pictures**, **make markups** and **annotations**, and **share documentation**
- Because some of their service outlets and dealerships are in remote areas, **the system must perform well in low bandwidth** environments and **by cell phone**
- Recognizing that no rollout of new technology would succeed without buy-in from the end-user, it **must be comfortable and safe to use in the shop**

7.1.1.2 HATCH – Remote Inspection and monitoring in Projects and Operations

Like Volvo Group, HATCH has used Librestream to combine field technicians with offsite experts (Hatch, 2020). In this case they use a body camera and a laptop/tablet, where the expert can change view perspective, and by this get the ability to direct the technician to a location of interest.

For this use case, no reflections on hardware/software abilities, etc. are presented.

7.1.1.3 Pratt & Whitney – How they use AR to enhance their support abilities

Pratt & Whitney makes aircraft engines, and as part of their operations they face a need to support their customers with various service and maintenance tasks. However, logistics and availability may limit the physical presence of Pratt & Whitney Field Support Representatives (FSRs) at customer sites.

To solve this issue, they offer remote assistance to their customers via the Librestream Onsight platform, which customers use with their smartphones (Figure 3). It is mainly used for guidance or training in various situations to help and support customers (P&W, 2020).

Figure 3. Pratt & Whitney using Librestream Onsight for aircraft engine remote support (P&W, 2020).

Some of the features that P&W specifies as important were: "Seamless remote collaboration, including Onsight's **low-bandwidth capability** and **functions such as taking photos**, **recording videos**, sharing high-definition stills, and telestration, which allows users to digitally "sketch" over top of videos and images" *(P&W,2020).*

7.1.1.4 Mercedes-Benz - Cutting edge technologies provide game changer for automotive icon Mercedes-Benz

With modern cars becoming more and more complex, complexity in servicing and troubleshooting problems cars at Mercedes-Benz dealers is increasing exponentially. To overcome this challenge Mercedes-Benz USA (MBUS) provides expertise to dealer service centers to resolve problems (Microsoft, 2020).

The traditional way of phoning and emailing back and forth is slow and inconvenient for the technicians, which makes the process inefficient and problem solving takes multiple days. To solve this issue, they have implemented Microsoft HoloLens together with Microsoft Dynamics Remote Assist (Figure 4). This solution saves significant time for the technicians, as the expert can be digitally by their side regardless of whether they are 30 or 3000 kilometres away.

Figure 4. Mercedes-Benz using Microsoft Remote Assist to improve service and problem-solving capabilities (Microsoft, 2020).

According to Juergen Pietsch, Department Manager for Field Technical Services at MBUS, "This technology is a great tool to get there by providing immediate onsite support, but also to use the opportunity to coach and train technicians for the future." He also adds, "Dynamics 365 Remote Assist is step one for Mercedes-Benz. We have other visions with HoloLens 2: mixed reality diagnostic paths, peer-to-peer collaborations, virtual reality training, even on the sales floor—using mixed reality to show accessories. HoloLens 2 and Remote Assist is the beginning of a new adventure."

7.1.2 AR & MR for teaching

Augmented Reality (AR) and Mixed Reality (MR) can be used in teaching to enhance the learning experience for students. AR and MR can be used in a variety of ways to support teaching and learning. Overall, the use of these technologies in teaching can make learning more interactive, engaging, and effective, as well as improve accessibility, foster creativity and critical thinking.

7.1.2.1 HoloAnatomy app

HoloAnatomy is a type of AR or MR app that is designed to help students learn anatomy. It was developed by Case Western University and Cleveland Clinic, and it uses Microsoft's HoloLens augmented reality technology to teach anatomy to medical students (Case Western University, 2017).

By using a smartphone or a tablet, the app can display 3D models of the human body in real-time, allowing students to explore and interact with the anatomy in a virtual environment. With HoloAnatomy, students can explore the human body, view internal structures and organs, and even perform virtual dissections and surgeries (Case Western University, 2016). The app can also provide information and educational resources on the different structures and functions of the body. In a few words, it is used as an educational tool to help students understand and learn about anatomy in a more interactive and engaging way, supplementing traditional textbook-based learning methods.

Additionally, this app can help students to better visualize and understand complex anatomical concepts, which can lead to improved learning outcomes and a deeper understanding of the human body. In fact, at Case Western Reserve University, they did a trial with their students where the students that had been in the HoloLens lab scored 50% better compared to the rest of med school class.

The app is based on AR and MR technologies. The key technologies that HoloAnatomy app include are the following (Case Western University, 2016):

- Computer Vision: The app uses computer vision algorithms to detect and track objects in the real world, allowing virtual objects to be accurately placed and anchored in the user's view.
- 3D Modeling: The app uses 3D modeling to create virtual models of the human body, which can be viewed and interacted with in real-time.
- Interactive Graphics: The app uses interactive graphics to provide an engaging and intuitive user experience, allowing users to interact with virtual objects and control the app's features.
- AR or MR Engine: The app is powered by a specialized AR or MR engine, which manages the app's AR or MR functions and helps to render virtual objects and information in real-time.

This app has several benefits and implications as a solution for learning anatomy. Firstly, learning outcomes are improved as the trial made at Case Western University has shown. The app provides an alternative learning method for students with different learning styles, including visual and kinesthetic learners, who may benefit from a more hands-on and interactive approach. So, the app increases accessibility. It also supplements traditional learning methods such as traditional textbook-based learning methods, providing students with additional resources and educational materials to help them understand complex anatomical concepts.

7.1.2.2 Chemistry cards and QR codes

Using AR for chemistry cards and QR codes is a way to enhance the learning experience for students by providing interactive and engaging content. This can be done by printing QR codes or special markers on chemistry flashcards or lab equipment, which when scanned with a phone camera, will start an AR experience. This experience can include 3D models of molecules, videos demonstrating experiments, or interactive simulations. It can also include additional information and resources, such as the properties and uses of different chemicals (Plunkett, 2019). This can make studying and learning chemistry more fun, interactive, and easy to understand.

At Organic Chemistry I, notecards where QR codes appeared to provide differentiation between reactions and for students to see how each reaction is formed in a very visual and easy way (Figure 5).

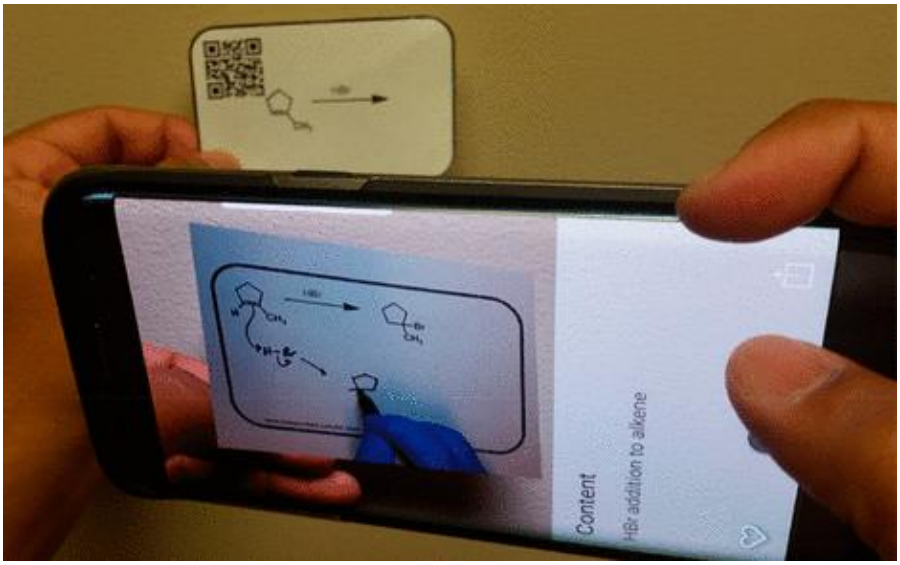

Figure 5. Real-time image of an AR video projection of Organic Chemistry AR notecard onto a smart phone (Plunkett, 2019).

7.1.3 AM & MR for training and instructions

AR can be used to guide users on how to use lab equipment by overlaying virtual instructions and information onto the user's view of the equipment through their phone camera. This can include step-by-step instructions, videos, or 3D models to help users understand how to operate the equipment correctly and safely. AR can also be used to provide real-time information about the equipment, such as its status or any potential issues. This can help to improve the efficiency and accuracy of training and reduce the risk of errors or accidents in the lab. Additionally, this has been proved in a chromatography machine as the following Figure 6 shows.

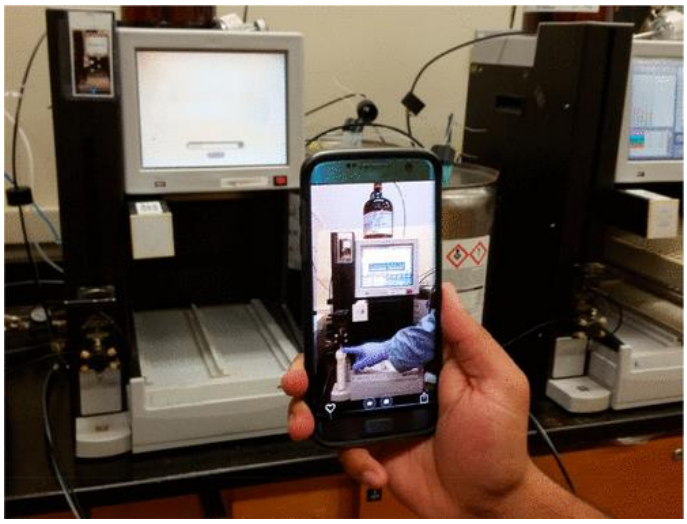

Figure 6. Real-time image of an AR video projection of AR instrumentation demonstration on a smartphone (Plunkett, 2019).

7.2 Technical solutions and suppliers

As has been seen before, different companies have chosen different equipment for the same purpose, guide through augmented reality. For example, Volvo has chosen to use RealWear HMT-1 hardware solution while Mercedes Benz decided to use HoloLens 2. Regarding all this information and after doing some research we wanted to know which equipment is most suitable for this project. At first glance, both technologies appear to be very similar and appropriate for the aim of this project, but it is necessary to choose one of them.

RealWear HTM-1 and Microsoft HoloLens 2 are both wearable devices designed for enterprise use cases such as industrial inspection, maintenance and repair, and remote collaboration. However, there are some key differences between these two devices as Table 1 shows.

Table 1. Further specifications on each device are provided below (VisionID, n.d.).

	Realwear's HMT-1	Microsoft HoloLens 2
Overview	The RealWear HMT-1 and HMT-1Z1 hands-free, voice operated head-mounted tablet computers are focused on Advanced In-Situation Training in rugged real-world industrial environments	The Microsoft HoloLens 2 is a 3D eyewear device, operated by voice or hand, that uses holograms to display information and blend into the real environment, working best in an indoor space. Windows compatible
Weight (g)	380	566
Battery (h)	8-10 (1 shift) – hot swappable	2-3 (can recharge to 70% in 15 mins)
Camera	16MP and 1080p60 video with digital zoom and stabilisation	8MP and 1080p30 video
Memory	16GB internal / 2GB RAM	4 GB DRAM
Storage	16GB + 12GB microSD	64 GB UFS 2.1
Controlled by	Voice Perfect noise cancellation (2 mics) to 95db	Hands and Voice Noise cancellation to 65db (5mics)
Connectivity	WiFi and BLE	WiFi and BLE
Audio	62db built in with jack for RPE-rated audio earbuds	Bone-conductive
Immersive experience	2D so less immersive, but also less intrusive. Displays information adjacent to the wearers field of vision and doesn't block the environment	Experiences rendered in 3D – more immersive. Some improvement in field of view in latest model
Industrial use	IP66, 100% dustproof and waterproof to 1m. 2m drop proof, can be used in dark and cramped work environments	IP50, some dust protection, not rated for drop. Not optimal in dark environments or cramped spaces
Operating Temps	-20 to +50 °C	+10 to +27 °C
Training focus	On the job training	Simulated training programs
Use Cases	Visual Assist, Remote Mentor, Document Navigator (workflows, data collection & reporting), Maintenance Asset/IoT, Training	Remote Support, 3D modelling on site (superimposed views, measurements, tracking walls & objects in room), Inspections, Training, Temperature
Software	Multiple applications available Vendors can customise solutions	Multiple applications available Vendors can customise solutions
Summary	Designed as a headset to allow industrial user to be focussed on knowledge transfer in the real world	Designed to immerse the user into a mixed reality world by superimposing holograms over the real environment

The RealWear HTM-1 and the Microsoft HoloLens 2 are wearable devices designed for enterprise use cases. The RealWear HTM-1 features a monochrome micro-display and is primarily operated through voice commands and a touchpad. On the other hand, the

HoloLens 2 boasts a holographic display that allows for the display of virtual 3D objects and information, and includes hand gestures, gaze, and voice commands as inputs.

While the HoloLens 2 is more advanced in terms of display and inputs, it comes at a significantly higher price than the RealWear HTM-1. The HoloLens 2 uses a Qualcomm Snapdragon 850 Compute Platform, while the RealWear HTM-1 uses an Intel Atom x5 processor.

Finally, the HoloLens 2 has a wider field of view than the RealWear HTM-1, which may make it more suitable for certain types of tasks. In conclusion, both devices have their own strengths and limitations, and the choice between the two will depend on the specific needs and requirements of the task at hand.

7.2.1 Cybersickness

Cybersickness, also known as virtual reality sickness or VR sickness, is a condition that some people experience after using virtual reality devices. In fact, it is a type of motion sickness. Between 20-95% of the users typically experience many symptoms such as headache, eyestrain, disorientation, sweating or nausea (Hughes, 2021). They can be caused by the disconnect between the visual and vestibular systems in the brain, which can be triggered by the immersive nature of virtual reality experiences. However, the symptoms and their duration can vary depending on the individual and the severity of their experience.

For some people, symptoms may disappear soon after they remove the virtual reality headset and return to the real world. However, for others, symptoms may last for a longer period, even a few hours after exposure to the virtual reality environment. Rarely, they may persist for a whole day or longer. Additionally, it is possible for people to develop a sort of acclimatation over time, which can reduce the severity or duration of symptoms. After exposure, lingering problematic effects as unstable posture, shifts vision and altered hand-eye coordination can appear.

For decades cybersickness has been researched and characterized in VR, but there is not that much information about how AR users are affected by this. AR devices superimpose virtual objects on the user’s view of the real world and can also cause a disconnect between the visual and vestibular systems in the brain, resulting in symptoms similar to those of virtual reality sickness. However, the symptoms of AR sickness may be less severe than VR sickness, as the user's view of the real world may provide a more stable reference point. Additionally, AR devices may have less latency and lower frame rates than VR devices, which can also contribute to the severity of cybersickness symptoms.

AR users normally experience headaches and eyestrain. These symptoms can have significant impact and be as severe as those related to VR when AR headsets are used for extended period of time. Understanding the impacts of long-duration AR exposure is critical and can help to mitigate the potential negative effects on users.

Currently there is no consensus on specific limit for the duration of AR exposure as it varies depending on the individual, the task, or the virtual environment. Nevertheless, experts generally recommend the users to take a break every 20-30 minutes of exposure and to take at least a 30-minute break before the next exposure (Hughes, 2021). This can help to reduce

the likelihood of experiencing cybersickness symptoms. However, these are general suggestions, and some people may be able to use AR for longer periods.

Another way to mitigate the effects is using multiple VR/AR technologies. Switching between a head-mounted display and a hand-held device such as a tablet or a smartphone can provide a break from the immersive virtual environment.

These are solutions that may be followed until it is possible to adapt the AR technology to the physiology of each user or individual.

7.3 Choice and test of selected technology and supplier

Regarding all the information mentioned above it is difficult to decide which equipment is the most suitable for the project. Both the RealWear HTM-1 and the HoloLens 2 are powerful wearable devices for enterprise use, but the HoloLens 2 may be more suitable for tasks that require a wider field of view, more immersive display, and more advanced processing capabilities, while the RealWear HTM-1 may be a more cost-effective solution for tasks that can be performed with voice commands and a monochrome display.

Choosing Microsoft HoloLens 2 over the RealWear HTM-1 for TapTesting in remote assistance might be a good option for several reasons.

Firstly, the holographic display of the HoloLens 2 can provide a more immersive and interactive experience, allowing remote experts to better visualize and understand the issues being faced by on-site technicians.

Secondly, the hand gestures, gaze, and voice commands inputs on the HoloLens 2 can provide a more intuitive and natural way of interacting with the device compared to the touchpad and voice commands on the RealWear HTM-1.

To finish, the field of view with HoloLens is wider so it allows remote experts to have a better view of the environment and the equipment being tested.

In conclusion, the HoloLens 2's more advanced display, inputs, field of view, and connectivity features make it a more suitable device for guiding technician in remote assistance (the aim of the project) compared to the RealWear HTM-1.

Reflections

- Both the XR10 (HoloLens) and the mobiWAN_TR (sound via bones) needs to be charged with USB-C. It should be considered to have a power supply with 2 USB exits, such that both can be charged at the same time.
- We need to make a smart way to setup the user for the HoloLens – such that it becomes plug-and-play.
- User needs fast intro to how to use the HoloLens and the hand gestures. Instruction on how to use windows home bottom
- Guides on setting up internet connection is needed
- Guide on setting up and connecting the mobiWAN_TR sound system
- Instructions on controllers for display brightness & sound

Instructions on positioning of the helmet and the HoloLens – relative to the user's head size, etc.

Based on the above comparisons of the RealWear HTM-1 and the Microsoft HoloLens 2, DAMRC has chosen to buy the Microsoft HoloLens 2 for the project and next step will be to choose what software platform we will use for the Microsoft HoloLens 2 (HoloLens).

7.3.1 Software platforms

Once the technology is selected, it is important to know which software are available. To maximize the device's capabilities, various software solutions are available to meet the specific needs of different industries and applications. These software solutions provide a range of features such as remote collaboration and assistance, maintenance, and repair and more.

7.3.2 Trimble connect for Hololens

Trible Connect is targeted at the construction industry. Their platform focuses on the ability to bring construction drawings and sketches out to the construction site – both for the designer and the construction worker to be able to see the planned installations (Figure 7, Figure 8, and Figure 9).

The idea is that planning, and design changes can be done more easily, and simply to support the workflow. As Trimble is also the supplier of the hardware (Trimble XR10 – MS HoloLens2) a seamless interaction is expected.

The software is listed at a price of 1799 $/license/year.

Figure 7. Visualizations of Trimble Connect for HoloLens (Trimble, n.d).

Figure 8. Trimble Connect. To the right: design review example. To the left: project coordination example (Trimble, n.d).

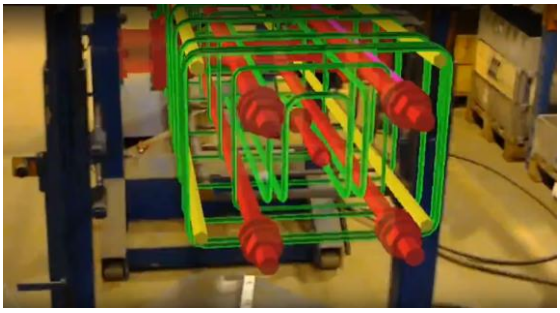

Figure 9. Trimble Connect. Visualization of production sequences step-by-step (Trimble, n.d.).

Based on the available information about Trimble Connects scope and capability, it seems to be targeted for another purpose than what is needed for this project.

7.3.2.1 Microsoft Dynamics Remote Assist & Guides

As part of Microsoft's Dynamics platform, they offer 2 software products to supplement the AR equipment. These are respectively Dynamics Remote Assist and Dynamics Guides.

The dynamics Remote Assist is a tool to support remote assistance from subject matter experts. Either via phone, tablet, or AR headsets users can call an expert to assist them. The selling point is that the expert has first person view, and can draw arrows, shows pictures, maps, and videos to guide the user as Figure 10 shows.

Figure 10. Dynamics Remote Assist - examples of uses (Microsoft, n.d-a.)

The Dynamics Guides is a supplementary tool that can be used to make guides and instructions for the user to follow (Figure 11). This could be on the sequence of assembling a part or in the case of this project, interactive instructions on how to set up the modal impact hammer system (TapTest).

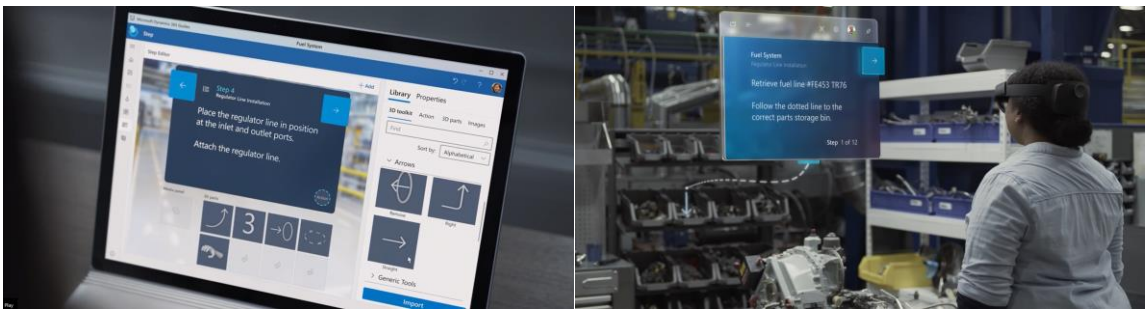

Figure 11. Dynamics Guide - examples of uses (Microsoft, n.d.-b).

Dynamics Remote Assist are quoted at 65 $/month (for Dynamics 365 Remote Assist) or 125 $/month (for Dynamics 365 Remote Assist with HoloLens 2) (Microsoft, n.d.-c).

Dynamics Guides are quoted at 65 $/month.

Both are preinstalled and ready to use together with the HoloLens.

7.3.2.2 VSight UAB

VSight delivers a software platform for Remote Assistance. Functionalities are similar to MS Dynamics Remote Assist, with ability to call an expert, have documents and other visualizations projected over real-world items (

Figure 12), to support completing a given task (VSight, 2023).

VSight supports Smart Glasses from: RealWear, Vuzix, Epson, Google & Rokid.

Pricing is unknown and requires placing a request.

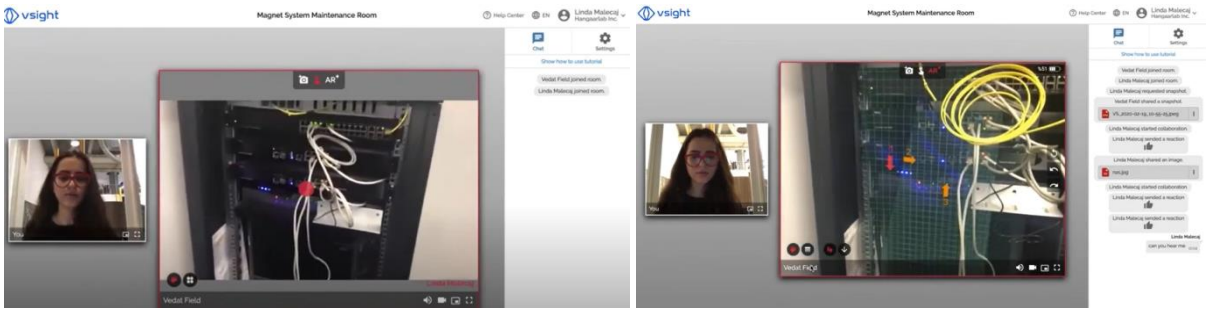

Figure 12. VSight Remote Maintenance Demo Video (Vsight, 2021).

Based on the needs for AR platform, VSight fulfills the most important need of remote assistance. However, they miss the functionality of creating instructions and guides for the user, which is expected to be of great relevance in the setup of the modal impact system. Based on their functionalities, they are only partly relevance for this project.

Further, the software is only compatible with the hardware suppliers. As there needs to be compatibility between the hardware and software, this may limit the use of the platform.

7.3.2.3 Librestream OnSight Augmented Reality Platform

Librestream provides their Onsight platform, a platform which includes functionality for remote assistance, digital guides, and work instructions (Figure 13), which together form a platform that can be used for knowledge preservation (Librestream, 2022).

One of Librestreams key selling points are their ability to stream and communicate a low bandwidths and poor internet connections. 30 kbps is enough for the platform to work. On the hardware side Librestream is compatible with: Apple, Dynabook, ECOM, Epson, Olympus, RealWear, Samsung and Vizix.

Pricing is unknown and requires placing a request.

Figure 13. Librestream Onsight AR platform - examples on use cases (Librestream, 2022)

From a technical perspective Librestream fulfills the functional need for the project. Nevertheless, one potential challenge would be their hardware partners.

7.3.2.4 ScopeAR

To finish, similar to Microsoft and Librestream, ScopeAR offers a platform for remote assistance and work instructions, the WorkLink Remote Assistance and WorkLink Instructions.

In the Remote Assistance the Technician and the Expert can draw on top of reality. In the WorkLink Instructions it is possible to generate instructions on e.g., assembly (Figure 14). What is unclear is if the WorkLink Instructions platform is only based on digital files, and CAD systems, or if it also can make simple instructions and guides on real physical equipment.

ScopeAR has a strategic partnership with Microsoft for easy integration to the MS HoloLens. However, they don't specify if their platform is compatible with other hardware solutions.

On the pricing ScopeAR starts at 299 $/month, while the professional offering starts at 15'000 $/year.

Figure 14. ScopeAR Remote Assistance and Instructions examples (ScopeAR, 2020)

From a technical perspective, ScopeAR has the functionalities that are required for this project (with some uncertainties on the instructions platform). Based on this this platform is qualified for the project. However, a limitation is that they apparently only partner with MS HoloLens on hardware connection. Further, they are relatively high priced.

8 Software selection

Regarding in mind all the information gathered in the previous section a comparison table (Table 2) has been made to decide which platform is the best for the project. It provides an overview of some of the most popular software solutions, their provider, price and how user-friendly they are for this project and benefits of each software solution, making it easier to choose the right solution for business needs.

Table 2. Comparison table for available software for HoloLens.

Software	Supplier	HoloLens	Price	Pros and cons
Trimble Connect	Trimble	Yes	1799 $/year	Focused on construction industry
Microsoft Dynamics Remote Assist and Dynamic Guides	Microsoft	Yes	65 $/year (Dynamic Remote Assist) 125 $/year (Dynamic Remote Assist with HoloLens) 65 $/month (Dynamic Guides)	Support remote assistance and make guides and instructions for users, can be used with Microsoft Teams, similar user interface as Microsoft Teams
VSight UAB	VSight	No	Unknown (Request needed)	Support remote assistance but misses the functionality of creating instructions and guides. Need of compatibility between hardware and software.
Librestream OnSight	Libretsream	No	Unknown (Request needed)	Includes functionality for remote assistance, digital guides, and work instructions. Ability to stream and communicate a low bandwidths and poor internet connections.
Worklink	ScopeAR	Yes	299 $/month 15000 $/year (professional offering)	Offers remote assistant and work instructions. No specification on whether their platform is compatible with other hardware solutions other than MS HoloLens.

Based on the above comparisons of the different software solutions and cost of these for the Microsoft HoloLens 2, DAMRC has chosen to go with the Microsoft Dynamics Remote Assist.

9 Experimental Design

To understand how HoloLens can be used to support the technicians in operating the Modal TapTest equipment usability tests have been conducted. This includes everything from how to handle that multiple users from different organizations will be able to access the HoloLens, to test of the AR software platforms in the context of a trial Modal TapTesting and general reflections on how to use the system.

The Microsoft HoloLens 2 delivered by Trimble was utilized for usability testing, equipped with a noise-cancelling sound system, and mounted on a safety helmet. The tests were conducted using the “MS Dynamics Remote Assist” AR platform, where the wearer of the HoloLens and recipient of remote assistance was referred to as the "Technician", and the one aiding as the "Expert".

9.1 TapTest.

9.1.1 What is TapTest

The Tap Test is an experimental procedure for measuring the impulse response of a structure to measure its frequency response function (FRF), characterizing the dynamic response of the structure to excitation applied at different frequencies. Tap testing is achieved by applying an impulse with an instrumented hammer and measuring the resulting vibrations with strategically located accelerometers. Data obtained from instrumented hammer and accelerometer are used to measure the FRF. In the metal cutting process, the structure to be investigated is the machine-tool holder-tool structure of CNC-machining systems. Modal analysis, a technique for extracting modal parameters from the measured FRF, is used in conjunction with data of the tool-machine structure and workpiece to identify cutting parameters resulting in stable cutting process. Unstable cutting results from, among other reasons, regenerative and mode coupling chatter vibrations, resulting in reduced surface quality, increased tool wear, and decreased productivity due to additional downtime. The tap test procedure using MetalMax software allows for the identification of cutting parameters that optimizes productivity, quality, and tool life while ensuring a stable cutting process. After the TapTest the following considerations must be observed when applying results obtained from TapTests: the optimized cutting parameters are valid only for the tool-tool holder-machine system that was tested. The results are not valid if any component of the above is changed.

9.1.2 Tap Test process.

There are two main parts in the Tap Test itself.

- Tap test the tool, save the stability lobes.
- Analyse the stability, give recommendations in standard reporting format.

The first part of the tap test, consisting of measuring the FRF of the tool itself, is fairly easy to do with some training when applied to standard milling tools with a diameter from 10-50mm, whereas tap tests of tools smaller than 10mm requires more experience is needed. However,

many companies use standard milling tools with a diameter between 10-50mmm as their primary tools, so there are theoretically many opportunities for untrained technicians to apply tap testing successfully.

The second part of the TapTest is the analysis of the stability lobe diagrams, which is done by the Tap Test engineer at DAMRC to leverage his or her expertise, as the analysis stage is a lot more complicated. The analysis by an experienced engineer is necessitated by the need to interpret the coherence, or measurement quality, of the measured FRF, assess the validity of extracted modal parameters and corresponding insights, verify the correctness of input data and software settings, as well as determine whether the test procedures for tap testing should be adapted for a specific tool or machining setup.

The procedure for tap testing as conducted by the project participants is as follows:

- Connect all hardware components to the laptop, and then start TXF software.
- Set the appropriate settings of the tool and material used.
- Calibrate the sensors.
- Input data in Setup window.
- Securely attach the accelerometer to the tool.
- Take practice measurements in any measurement direction of the tool.
- Take FRF measurements for all enabled measurement configurations.
- Generate the DOC stability lobe diagram.
- Save the stability lobe diagram on a USB key.
- Send the stability lobe diagram to the DAMRC Tap test engineer.

A more detailed step by step video of the process is made in uQualio and on paper for the participants.

9.1.3 Purchase of new Tap test equipment.

In the beginning of the project, it was clear that the old tap test equipment (10+yers) at DAMRC was outdated, upgrading the equipment is supported by several factors and considerations. The most pressing of these is the fact that the hardware included with original equipment is now very dated and the associated tap test software is designed for use on 32-bit computers and limit to Microsoft Windows 7 32bit which Microsoft does not update any more. This presents significant risk that there will be substantial difficulty in securing support for technical issues for both the hardware (for example the DAQ card) and the software from original vendors, and, moreover, exposes DAMRC to potential cybersecurity threats by using a dated operating system. The newer version of the tap test equipment mitigates these issues by using more up to date hardware and 64-bit software.

The newer (2022, 64-bit) version of TXF also includes additional features that facilitate tap testing. One of the most beneficial of the new features is the inclusion of additional tools to expedite the extraction of modal parameters from the measured FRF to be used by the DAMRC Tap test engineer when analyses the Tap test stability lobe diagrams send by the p participants in the project. This feature is decisive for reducing time spent analysing the measured data to identify vibration modes and resonance speeds of the machine-tool structure. The newer version of TXF also includes additional software modules that allow the

tap testing procedure to be adapted to more machining operations. A comparison of the features in the new and dated versions of the TXF software is outlined in **Fejl! Henvisningskilde ikke fundet.**. The decision to upgrade the tap test equipment was made due to these considerations as well as the opportunity to purchase additional MetalMax software (i.e. SpinScope).

Based on the experiences, DAMRC have had with the new 64 bit equipment, it was decided to upgrade the dated 32 bit equipment – enabling DAMRC to have to updated and equal systems.

Table 3: Comparison of selected features in 32 - and 64-bit versions of TXF software

Feature	General Description	32-bit Tap Test (2009) (version 8.00)	64-bit Tap Test (2022) (version 2022.02.14.00)
Cutting module	The cutting module is an option in the Project tab of the TXF Setup window, allowing the user to specify the type of machining operation to be optimized (i.e milling, turning, drilling etc.) More cutting modules are available in the 64-bit software.	• Milling • Small Tool Milling • Helical Milling • Milling RCSA • Boring • Turning	• Milling • Face/Feed Milling • Plunge Milling • Trochoidal Milling • Thin Wall Milling • Small Tool Milling • Helical Miilling • Boring • Turning • Blade Milling
Stability Lobe Diagram	The stability lobe diagram provides a plot of chatter limit and spindle speed presenting a “landscape” of stable cutting parameters. An additional plot of chatter frequency vs spindle speed is also provided More features are available in the 64-bit software.	• Has standard stability and chatter frequency diagrams with resonant speeds and tooth passing harmonics. • Stability diagram presents stable depth of cut (mm) on the vertical axis for boring cutting module.	• Has standard stability and chatter frequency diagrams with resonant speeds and tooth passing harmonics. • Stability diagram presents feedrate (mm/rev) on the vertical axis for boring cutting module and plunge milling module. • Both base and target cutting parameters can be plotted on the stability diagram • Can highlight the most flexible natural frequency in the chatter frequency plot
Modal Analysis	The modal analysis tab allows a best fit curve to be applied to the measured FRF. The curve is applied to each individual mode (“vibration peak”) to create the overall or global fit of the FRF. This feature has applications in identifying modal parameters (mass, stiffness, damping) and in creating the yellow resonance bands in the stability lobe diagrams within in TXF.	• Options to add, delete, and edit vibration modes. • Can adjust bracketing frequencies for peak fitting using the edit feature or with the mouse on the FRF curve.	• Options to add, delete, and edit vibration modes. • Can adjust bracketing frequencies for peak fitting using the edit feature or with the mouse on the FRF curve using the mouse is easier/more intuitive.

	The 64-bit software offers improved and more user-friendly peak fitting features, summarized to the right.	• Fit FRF peaks in real/imaginary representation only • Individual FRF peaks must be fitted one at a time	• Can fit FRF peaks in both real/imaginary and magnitude representation. • Peak magnitude is included in identified modal parameters. • Has additional options to automatically fit and refine all modes, rapidly increasing time for curve fitting when multiple peaks are involved. • Provides statistical measures of the quality of the curve fit. • Provides an estimate of static stiffness.

9.2 General test of Hololens – Getting started

When starting up the HoloLens follow needs to be done:

- Turn on the HoloLens
- Understand the basic gestures for logging into the HoloLens
- Login – this must be done with a work-account user (@damrc.com account) or by setting up the HoloLens in "kiosk mode".
- Connection to internet
- Connection to the sound source (either bone connect or wireless ear pods)
- Learn the basic navigation & usage principles
    - Window bottom
    - How to exit apps (close "X" or Windows Home-bottom)
    - How to select by tapping or air tapping
    - How to move the windows around
    - How to make the windows float (follow the user) or pin it to a specific location
    - How to turn up / down the sound level and HoloLens brightness

9.3 First test of HoloLens with MS Dynamics Remote Assist

The first usability testing of the AR system will be performed on the 14th of June 2022. The purpose of the test is to try out the MS Dynamics Remote Assist application and evaluate if the application has the capabilities needed to assist and guide the user.

The test will be conducted by R&D Engineers at DAMRC. The test is designed to simulate an industry alike situation, where the technician needs to unpack the Modal TapTest equipment, connect the hardware, setup the software correctly, and complete a TapTest measurement on an endmill in a CNC-milling machine.

One DAMRC engineer will act as Technician the first half of the test (setting up the hardware), while another engineer will guide him as the Expert. Midways a switch will be made, such that

one of the DAMRC engineers will be the Technician, and the other one the Expert. The Technician will use the HoloLens for communication throughout the hole test, while the Expert will be in a meeting room at DAMRC communicating via MS Teams.

The complete test (without instructions on how to unpack, startup and operate the HoloLens) took approximately 1 – 1,5 hours, including TapTesting one tool. The test was performed such that only the HoloLens were used as communication media for the Technician.

9.4 Second test of Hololens with MS Dynamics Remote Assist and Screen Control for Taptest PC via Teams

A second test will be conducted on the 15th of June 2023 taking into account the learnings and reflections from the first usability test. In this test a DAMRC engineer will act as a technician while another DAMRC engineer will be the expert.

In this second test the scope is to evaluate the feasibility of using wireless ear pods instead of mobiWAN bone connect and see if it has any compromises, to determine if the TapTest PC can be included in a Remote Assist Teams call, to assess if an expert can take control of the screen during the call, to observe any side effects from this, and to examine the impact of using different internet connections on the call to see if it is still possible to perform it.

To add the TapTest PC to the Remote Assist Call the following sequence must be followed:

1. Start up the Remote Assist Call from HoloLens to Expert.
2. The Expert answers the call.
3. Open MS Teams, the account on MS Teams should be the same as used in the HoloLens.
4. Click “attend” in existing call.
5. Select “add this unit to the call”. You should not select “transfer the call to this unit”.

It is important to highlight that it is always the HoloLens Remote Assist the one that needs to initiate the call.

The use of screen control for software setup has been tested and is functional. To share the PC in MS Teams, the Technician needs to press "share screen " and select "screen / skærm" (Figure 15). The Expert can then request "take over control " which the Technician must grant, allowing the Expert to navigate the TapTest PC remotely and perform the complete software setup for the Modal TapTest equipment. While the system works, it requires a significant amount of internet bandwidth, which could pose a problem for remote software setup.

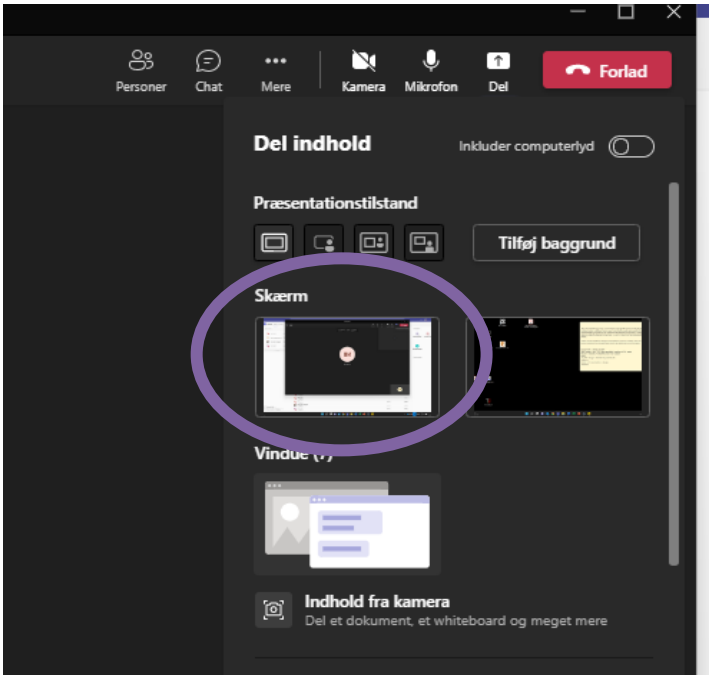

Figure 15. Snapshot of screen sharing functionality, and what screen to choose.

9.5 Third Test – Remote Assist testing using unbiased "Technician"

As a third and final test, an intern at DAMRC without any existing knowledge about the Modal TapTest equipment or HoloLens was assisted in setting up and use the equipment. This is perceived as the final test, to verify if it is possible to effectively assist and guide the Technician in the use of the TapTest and Harmonizer equipment. Result??

9.5.1 Result of third test:

Below there is a list of challenges that the intern DAMRC employer had under the test with the HoloLens and tap

- Challenge to see all 4 corners in the glasses.
- It was a challenge to see the uQualio videos when using the HoloLens at the same time.
- language change just happened randomly.
- Paper instructions are not easy to use when using the HoloLens at the same time.
- External sound is low with the bone connected as they were hard to place correctly on the head.
- uQualio videos are not easy to see on a mobile phone during test.
- Didn't understand how to tap things out of reach (air tap) but got a hold on it after some time.
- Has to take a break and lay down to overcome cyber sickness. (h

As this was a test just as much on have the uQualio guide videos worked in preparing the test person for the HoloLens, it was decided to skip the Taptest itself as the test person got cyber sickness, and it took the rest of the day before the symptoms disappeared again.

Table 4: Challenge and solution on challenge based on third test results.

Challenge:	Solution
Watch the uQualio videos, without the helmet on	Send the video before the test, so that the participant can see them and prepare before the test
After a 15 min break the helmet goes to sleep. – Either remove this or instruct that this will happen!	Turn of the sleep mode
Paper instructions is not easy to read while testing.	Make the paper instructions simpler, maybe by having more pages, but only 1 action/information per page
Low sound from the bone headphones	Make a new and better 3D printed attachment for the bone headphones.
Challenge to see all 4 corners in the glasses.	Use more time on the calibration in the beginning of the setup of the hololsen.
uQualio videos are not easy to see on a mobile phone during test.	Make it possible to see the uQualio on the Taptest computer for a lager screen.
Test person must take a break and lay down to overcome cyber sickness	Very different how different people experience cyber sickness and can vary a lot from person to person. (Remember to instruct the test person about cyber sickness and have to deal with it.)

Figure 16 and 17. DAMRC intern using the HoloLens and laydown after experience cyber sickness.

10 Usability test

10.1 First internal usability test

10.1.1.1 Battery

After 1,5 hours of use, the power level was at 2/5, something between 30-50% remaining battery. Thus, it must be expected that battery life is limited to something between 2 and 2,5 hours of continuous usage.

10.1.1.2 Connectivity

The tests were done on the DAMRC-C network (the primary network of the DAMRC). The ping ranges from 5-8 ms. The download from 200-400 Mbps and the upload from 200-450 Mbps. At the first test, no remarkable internet connection issues were observed.

The following Figures are visuals from the first usability test (Figure , Figure 19, Figure , Figure , Figure 22, Figure 23, Figure 24 and Figure):

Figure 18. Guide arrows on what hardware to unpack. Similar is used in the assembly process.

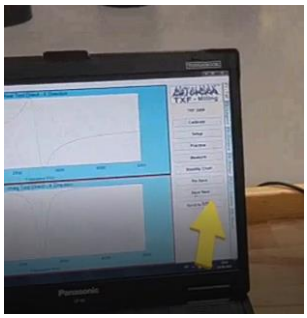

Figure 19. Assistance on what to do in the TapTest software (TXF).

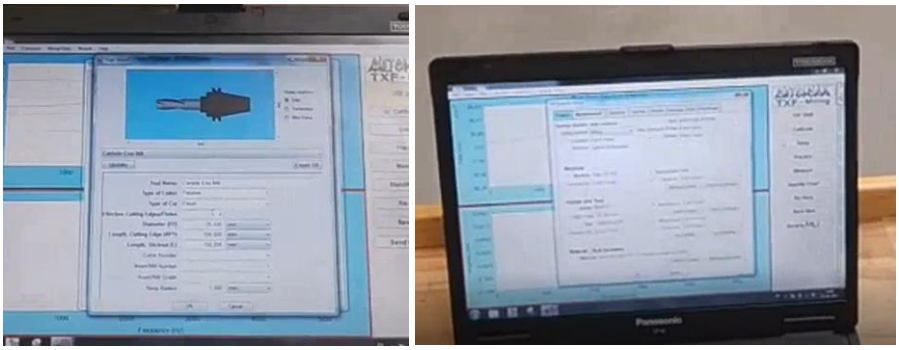

Figure 20. Examples on the setup menu. It is hard to see the text in the PC and similarly it is hard to precisely add guiding arrows.

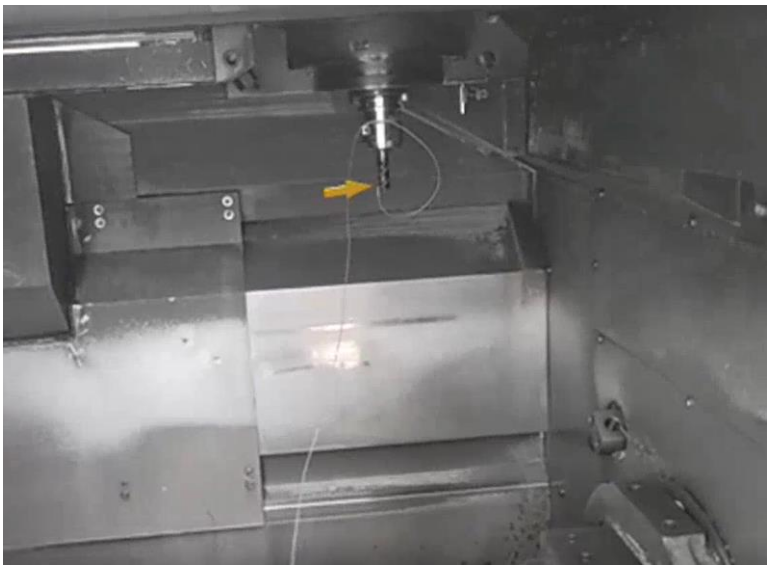

Figure 21. Guiding arrow for where the accelerometer should be placed.

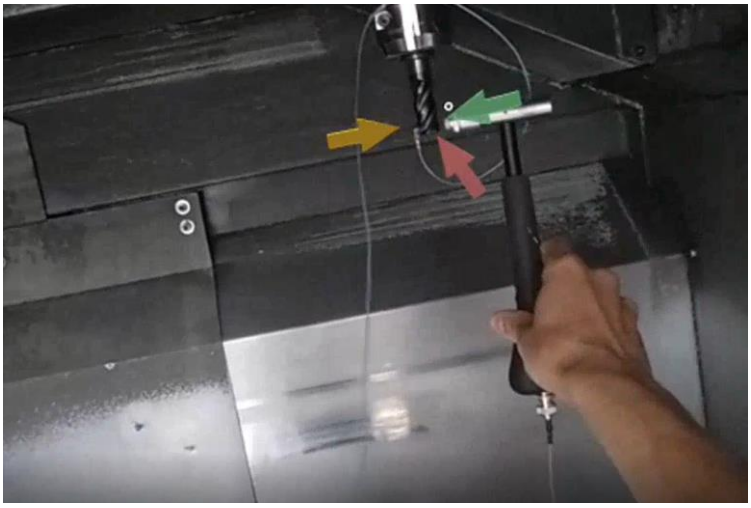

Figure 22. Where should the accelerometer be. What direction to hit from (green arrow). What direction not to hit from (red arrow)

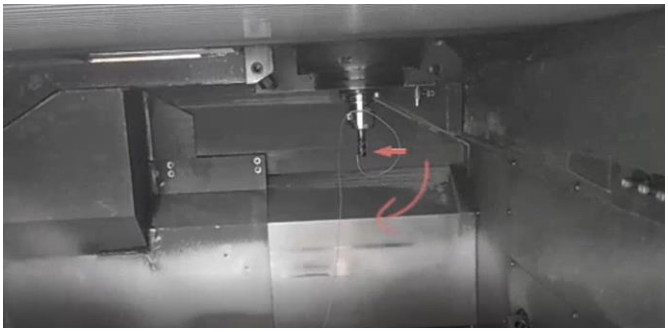

Figure 23. Instructions on how to rotate the tool for Y-axis measurements.

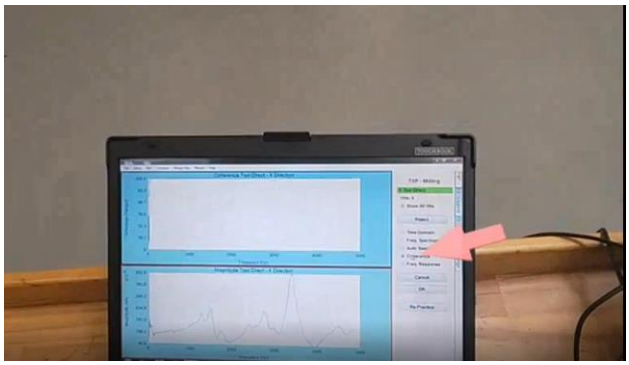

Figure 24. Support on controlling the PC during measurements.

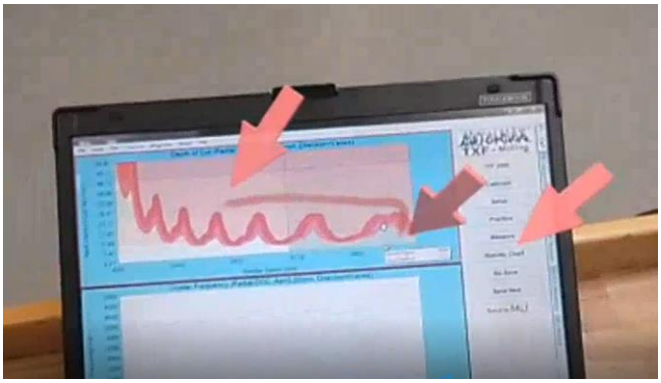

Figure 25. Example of how the arrows can guide (or confuse) the Technician.

10.1.2 Second internal usability test

10.1.2.1 Internet connections

Different internet connections were tested to see their effect on the system. One test was done using DAMRC-C internet connection which had a ping of 5-7 ms and 200-450 Mbps upload and download. It was possible to run the Remote Assist call and add the PC for remote screen control, but there was a freeze at the expert's screen at some point and the PC had to leave and re-enter the call.

The DAMRC-Guest network and local mobile hotspots via smartphones were also tested, but it resulted in poor internet connections which challenged communication significantly. The

results call for the need to know if participating companies have a strong enough internet connection for the system to work properly.

DAMRC-Guest had a ping and up and download similar to DAMRC-C network. The local mobile hotspot via a smartphone had a ping of 22-48 ms and upload of 1,5-15 Mbps and a download of 13-24 Mbps. The local mobile hotspot via Inigo's smartphone (roaming due to Spanish SIM provider), had a ping of 58, upload of 1,5-28Mbps and download of 1,5-45Mbps. For both local mobile hotspots it was possible to do a normal Remote Assist call – even though more "lag" was observed. However, when adding the PC via MS Teams and doing screen- and control sharing, the latency and poor connections made it impossible to do any decent communication.

Based on the experience with poor internet connection the requirements for both MS Dynamics Remote Assist with HoloLens and screen sharing with MS Team was investigated.

What is clear is that the requirements for the internet connections are a low ping (preferably below 10), and that up- and download formally should be above 10 Mbps. However, the tests showed that even with 200 Mbps connectivity challenges occurred. Thus, to ensure the highest likelihood of functionality the participants should have connections of +100 Mbps. Below this, they should know that the quality of assistance might be compromised.

For MS Dynamics Remote Assist the recommended speeds are (Microsoft, 2022a):

- Minimum 1,5 Mbps up- and download, for HD 1080p at 30 fps – this might make the system work, by quality can be compromised.
- Ideal 4-5 Mbps or more should be available – and preferably more as the full quality might still be compromised at this internet speed.

For MS Teams the recommended bandwidth speeds [Mbps] are the ones shown at Table .

Table 5. Recommended bandwidth speeds (Mbps) for MS Teams (Microsoft, 2022b).

Modality	**Bandwidth requirements (Upload / download)**		
Screen sharing	**Minimum**	**Recommended**	**Best performing**
One to one	0,20 / 0,20	1,50 / 1,50	4,00 / 4,00
Meetings (multiple)	0,25 / 0,25	2,50 / 2,50	4,00 / 4,00

Minimum recommended and best performance bandwidth requirements are based on per-endpoint usage. Typically, there's one endpoint per user, such as a computer or mobile device. However, if a user joins a Teams meeting on both a computer and a mobile device, two endpoints are associated with that user. This means that if both a PC and the HoloLens (at the company) are connected to the same meeting, the requirements for best performance doubles, i.e. +10 Mbps should be available.

11 External company field test

To finish with the experiments between different companies some of them will be selected to prove this technology. The idea is that a DAMRC employee will assist them through remote assistance while they do the TapTest. They will receive all the necessary material prior the tests and they will fill the survey after realizing them.

11.1.1 Screening and selection of participating companies

A screening of companies (table 6) based on 3 elements were set up;

1. Manufacturing companies using CNC-machines
2. Geographical spread to (incl. ara of interest for Norlys Vækstpulje & Færch Foundation)
3. Level of knowledge about Taptest

Some of the companies are displayed in table 6.

The companies have been screened on whether they were located inside Norlys geographical work area or not if they have machines and production with CNC processes. And if they have prior experience with Taptest.

Table 6. Screening of companies: above list is only some of the companies there was in scope for this project.

Name	**Adress**	**Geographical spread**
VOLA	Chr Nielsens Vej 3, 8700 Horsens	East Jutland
TERMA	Terma A/S, Hovmarken 4, 8520 Lystrup	East Jutland
PL-Valves	Mandal Alle 25, 5500 Middelfart	Funen
Vald. Birn A/S	Frøjkvej 75, 7500 Holstebro	West Jutland (Færch)
IPL Production A/S	Nylandsvej 5-7, 6940 Lem St.	West Jutland
Hein & Sønner	Lollandsvej 2, 8940 Randers	East Jutland (Norlys)
Lego Form Tooling	Kløvermarken 14. 7190 Billund	South Jutland (Norlys)
Linak Danmark	Mønstedsvej 9, 8600 Silkeborg	Mid Jutland (Norlys)
Randers Gears	Haraldsvej 19, 8960 Randers	East Jutland (Norlys)
Formkon A/S	Oddervej 5, 7800 Skive	Mid Jutland (Norlys)
Prodan A/S	Tåsingevej 1, 8940, Randers SV	East Jutland (Norlys)
LPM production a/s	Energivej 34, 6870 Ølgod	West Jutland (Norlys)
Fagerlunds Værktøjs- og Metalvarefabrik A/S	Haunstrup Hovedgade 24, 7400 Herning	Mid Jutland (Norlys)
Ejnar Hansen Maskinfabrik A/S	Smedevej 7, 6310 Broager	South Jutland (Norlys)
OKM A/S	Fabriksvej 21, 6270 Tønder	South Jutland (Norlys)
Grundfos A/S	Randersvej 22, 8870 Langå	East Jutland (Norlys)
EasyPartz	Maskinvej 5, 2860 Søborg	Zealand

The companies screened have been asked to participate in the project and the three companies Vald. Birn, Hein & Sønner and EasyPartz volunteered to be case companies. Vald. Birn was the 1st test company due to timing, need and positive attitude towards testing the technologies.

11.1.2 Test Vald. Birn – Field test

The first test was conducted at Vald. Birn with Michael Pedersen (Industrial Technician). Michael had formerly been working at DAMRC and therefore he knew what Taptest is and the principles behind it but had never used the equipment. This made him the perfect first test person, as he had the prerequisites of understanding the Taptest.

The uQualio material and Taptest equipment was delivered to Vald. Birn two weeks before the actual test to give them time to go through the introduction material of guides and checklists. At the test day Michael came prepared and went through all the given introduction material.

The test day started with a look at the machines and processes that were meant to be tested. Then in a meeting room close to the production the DAMRC engineer went through the Taptest and HoloLens equipment together with Michael.

Figure 26. Michael Taptest with guidance from Taptest technician though Hololens.

Michael did the setup and preparation of the first machine with the guidance from the engineer (which engineer) beside him. Once he was ready to begin the Taptest, Michael called the DAMRC engineer that was in the meeting room using the the Microsoft Teams install on the HoloLens and successfully used the functions of the HoloLens to communicate and ask questions to perform the Taptest. After the first tool was done the technician (which technician) got the data and used it to determine new optimized parameters to be tested. This process was conducted a second time on another tool. The data was collected by the DAMRC engineer, who processed the data and afterward sent the Taptest report to Vald. Birn.

11.1.2.1 Evaluation

The test process ended with an evaluation using the Hololens questionnaire that can be seen in APPENDIX B – SURVEY. In the survey the respondent rates the user experience on a scale of 1-5 where 1 is bad and 5 is very good. The discussion that came of the questionnaire can be summed up to the following points:

- Michael was annoyed that uQualios video player stopped and did not give indications that the user had to take action to move on and it was not just a bad connection.

- Michael did not find the interface of the Hololens user friendly. It was annoying to go through the settings to setup to wifi, it should be part of the setup.
- The video connection couldn't show the screen of the Taptest computer and would like some improvement on that.

The rest of the functions Michael was happy about and rated either with a 4 or 5.

11.1.2.2 Taptest result

On the test day 2 tools were tested, tool 1: 249231163_18_Trinfraser and tool 2: EFRA_20_0136, the results of the Tap test itself where good and stable stability lobes where identified and new optimized parameters can be tested, and if they can run at maximum parameters there is a 43% increase on tool one and 38% on tool two in metal removal rating.

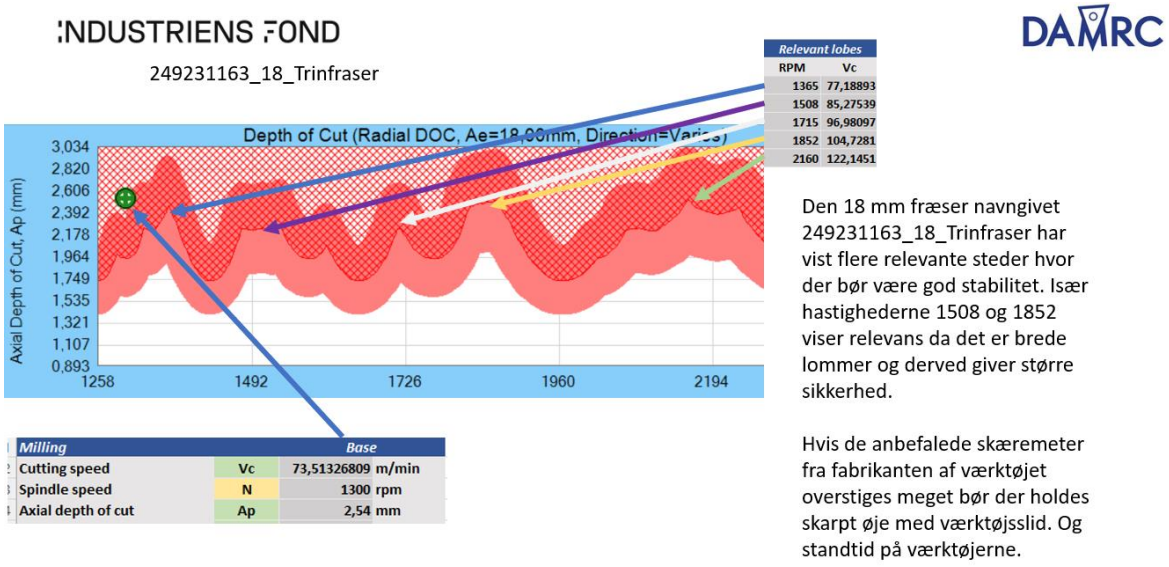

Figure 27. Part of Vald. Birn report showing stability plot and relevant lobes.

Figure 25 shows multiple relevant lobes that are pointed out together with the base parameters. The report was handed over to Vald. Birn for them to have the information and test out different recommended parameters if necessary, enabling Vald. Birn to gain the optimization.

11.1.3 Test at Hein & Sønner – Field test

DAMRC tested the remote optimization at Hein & Sønner the 12th of July 2023. Just as with Vald. Birn, before the test links to the video material on uQuilio was sent to Kurt Stilling (Production director and owner) who would be performing the Taptest with guidance using the Hololens. When arriving at Hein & Sønner DAMRC was told that he had not seen the video material in preparation as he had not had the time to go through the 1-2 hours of material. This was noted as there might be a need for a quick guide. After the visit at Vald. Birn and before the visit at Hein & Sønner screen sharing software was installed so the remote support could see the screen of that Taptest computer during the data gathering.

After a setup in a meeting room Taptest the DAMRC engineer went through the equipment and introduced Kurt to the HoloLens. This was a larger introduction as Kurt had not seen the preparation material, but Kurt was fast to learn the basic function of the HoloLens, and was able to setup the wifi by himself with some small guidance from the DAMRC engineer.

After setup and introduction was complete the Taptest was done similar to the first test, the DAMRC engineer observed the setup of the equipment and did not intervene unless it was necessary, this went easily. Then he went to the meeting room to take a call from Kurt using the HoloLens though Remote assist and then guided him though the Taptest. One test was done without screen sharing and another test with screen sharing. The screen sharing was a positive thing as it made things clearer about what was supposed to happen in the Taptest software, and it cutgive a live view of the data collected.

11.1.3.1 Evaluation

The test process ended with an evaluation using the Hololens questionnaire that can be seen in APPENDIX B – SURVEY. In the survey the respondent rates the user experience on a scale of 1-5 where 1 is bad and 5 is very good. The discussion that came of the questionnaire can be summed up to the following points:

- Kurt says the HoloLens seems to be too much for the task. Less could have done it, if smaller was more user friendly. (Like a mobile phone or a small camera connected to the computer)
- It is a bit of a learning process with the windows disappearing all around, as the window can be attached to specific places due to the coordinates in the HoloLens
- Workshop sounds can disturb the instructions and can disturb the sound of the Hololens so you miss the information given by the engineer.
- Kurt says that the helmet is ok to wear, but not better either, because as he says, all such helmets are not nice to wear over a long period of time.
- The menu suddenly became small, Kurt tries to play around with it a bit to see if he can get it back to normal size. It turns out that it was the helmet that did not fit correctly as it has to place a little back on the head on Kurt.

The rest of the functions Kurt was happy about and rated either with a 3 to 5.

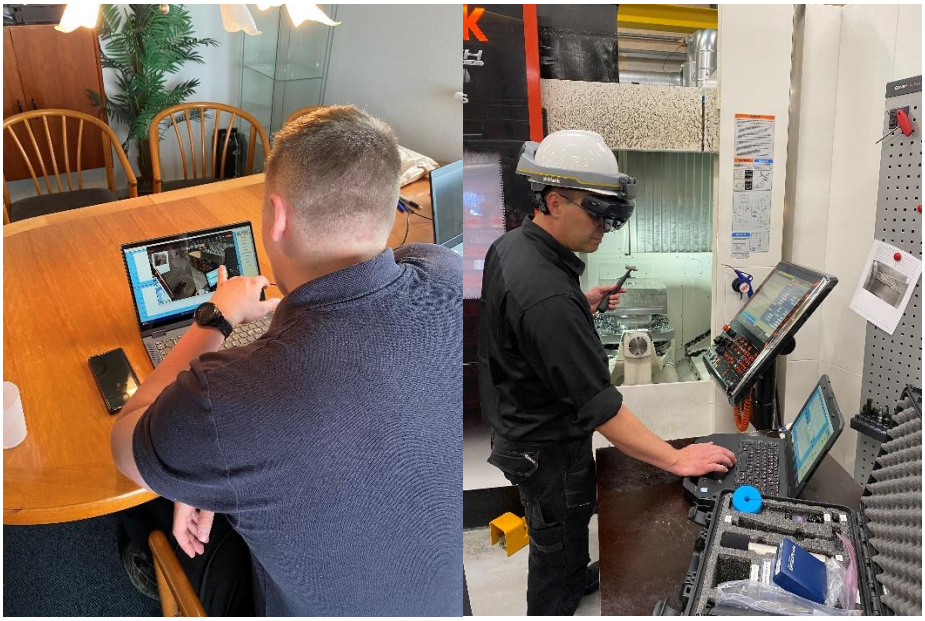

Figure 28 –Pic Left: picture of DAMRC engineer taking call from Kurt

Pic right: Kurt is Tap testing the tool in the machine while being guided by the DMARC engineer.

11.1.3.2 Tap test result.

On the test day there was tested 2 tools, tool one: 25mm miller and tool two: 20mm miller, the results of the Tap test itself were good and there was found some good stability lobes where identified and new optimized parameters can be tested, and if they can run at maximum parameters there is a 52% increase on tool one and 59% on tool two.

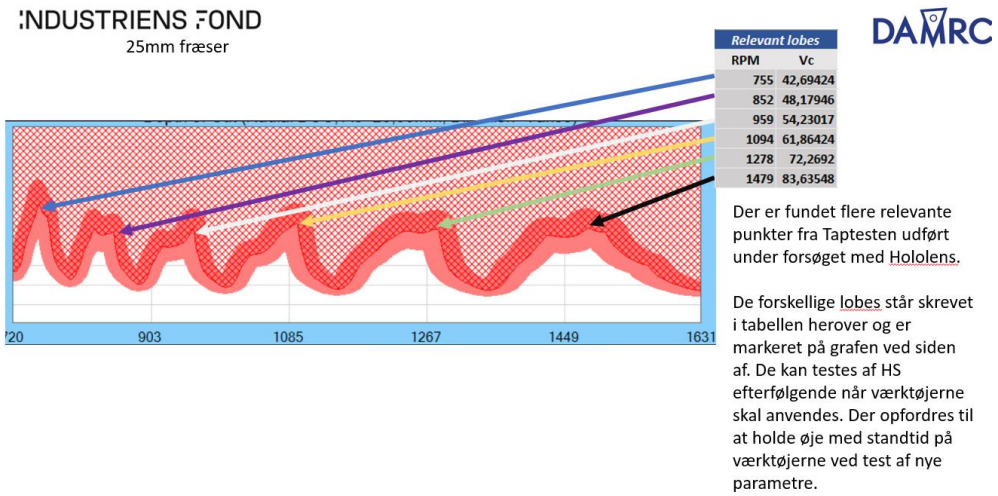

Figure 29 - Part of Tap test report made for Hein & Sønner

Figure 26 shows multiple relevant lobes to show there can be a good and stable base parameter, The report was sent to Hein & Sønner for them to test the different recommended parameters.

11.1.4 EasyPartz – Field test

DAMRC tested the remote optimization setup at EasyPartz over a period of 4 weeks form the 19/09-2023 – 10/20-2023. DAMRC has two sets of tap test equipment one 32bit (10 years+) and a 64bit bought in this project. The 64bit Tap test equipment were used for all the other test, but due to EasyPartz needed to lend the Tap test equipment over a longer period of time (4 weeks), and DAMRC is using the 64bit tap test equipment on daily basis due to the updated software (bigger material data base and so on), and all the materials that EasyPartz was using was in the 32bit tap test system, the choice was easy and 32bit tap test equipment was chosen for this test.

On the 19/09-2023 EasyPartz got training in the use of the tap test equipment and the HoloLens by DAMRC on site at EasyPartz. Peter (Production engineer) and Morten (CEO) from Easy Parts was taking part in the training, they were not introduced to the training videos on uQualio. But all in all, the test went well and both and Morten and Peter were quick to learn have they should perform the tap test and use the HoloLens. EasyPartz have earlier had a quite deep introduction to using the Tap test equipment.

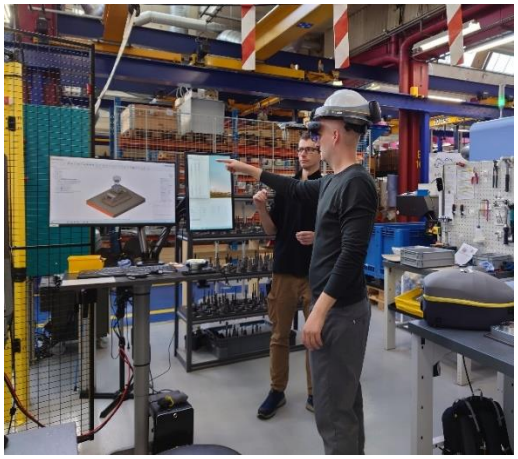

Figure 30: Morten from EasyPartz training on the HoloLens.

On the 17/10-2023 EasyPartz had a Microsoft Teams meeting with DAMRC where Peter from EasyPartz should perform a Tap test and was getting feedback from Alan, DAMRC through the HoloLens.

11.1.4.1 Evaluation

The test process ended with an evaluation using the HoloLens questionnaire that can be seen in APPENDIX C – SURVEY. In the survey the respondent rates the user experience on a scale of 1-5 where 1 is bad and 5 is very good. The discussion that came of the questionnaire can be summed up to the following points:

- The feedback received from Peter on the user feedback on the HoloLens was mixed. Micheal praised the HoloLens for the intuitive interface there was easy to navigate through.
- When you tuned it on for the first time it was easy to connect to the Wi-Fi and get Microsoft Teams up and running and make the call.
- It was a little hard to press the bottoms on the HoloLens screen sometimes, and there was also some problem with grabbing and pulling open windows (like Microsoft Teams) to the place where you need them to be.
- Peter also noted that the contrast/brightness of virtual objects on the HoloLens screen is affected by the angle through which one looks through the HoloLens, making a proper fitting and calibration of the helmet essential.
- Under the team call the DAMRC engineer tried to place some arrows to guide Peter, but the arrows were not placed correctly on the screen on the HoloLens and Peter was not able to follow the instructions from the DAMRC engineer very well.
- The comfort of the HoloLens was not that great but was okey for the short time he used it.
- The bone headphones were not easy to place at all, but when Peter got them in place the sound was ok, but it would have been better with some in ears with noise cancelling according to peter.
- The tap test was easy to do, when I got the right instructuion over the HoloLens
- One of companies made the remark that it was too much to focus on two new systems at one time (Tap test and Hololens). The most important system for the optimization is the Tap test system.
- Another remark was that the Hololens seems to be outdated – easier possibilities (i.e. camera in phones/ team meeting possibilities etc.) are available today – easy to handle and more intuitive.
- The HoloLens – in combination with the Tap test might be too much for an operator to handle, and more training is needed to become familiar with it and accustomed to using it

As a side note EasyPartz had the 32bit Tap Test system for the whole project time, which presented some challenges, as there is a slightly difference in how it is set up and how the shortcuts to the functions are in the 32bit (old version 10+ years) vs. the new 64bit Tap Test system, that we had here with us at DAMRC, which challenge the engineer who was guiding the user in the video call.

11.1.4.2 Tap test

The Tap test itself it was not difficult as soon as Peter got it under his skin, and learned have hard he should hit with the hammer, so several Tap tests was done successfully on 16 tools over the period, and on some of the tools we couldn't find any improvements as they were running on optimal parameters according to the stability lobes form the Tap test, and on other tools we found around 19-43% increase on metal removal rate.

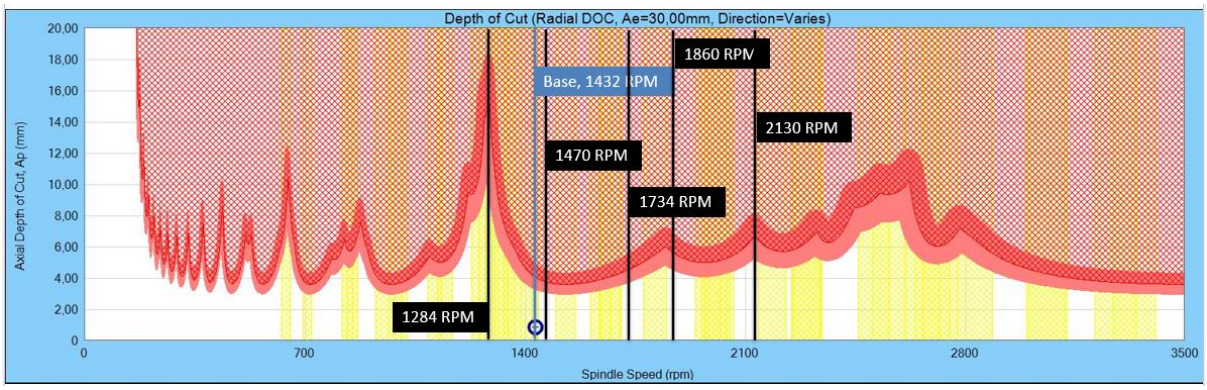

Figure 31 - Part of taptest report made for EasyPartz

Figure 31 shows multiple relevant lobes that are pointed out together with the base parameters. The report was sent to EasyPartz for them to test different recommended parameters.

12 Discussion

12.1.1 First usability test by DAMRC

After proving the HoloLens one of the DAMRC engineers experienced that tracking hands works but that it can be difficult to use it, So he suggests using the index finger to select. Remote Assist App works quite well guiding the user on-demand as arrows and still images can be used for that. However, he commented that it is hard for the expert to see the text on the laptop screen though the HoloLens, although the kiosk mode could not been set up, the main menu with 3 apps (Setting, Remote Assist and Guides) was setup, which will be more useful for technicians. The HoloLens battery was useful for 2 hours. Regarding the HoloLens helmet, wearing it can cause headache. In fact, this headache is caused by the helmet itself and the extra weight of the speakers. So, for some user it is more comfortable to remove the mobiles speakers and reduce weight and therefore decrease headaches due to the discomfort of the helmet. One of the DAMRC engineers felt a little sick for 20 minutes when he wore the helmet for the first time due to motion sickness. The next time he used the HoloLens he could use it for 30 minutes. Therefore, he recommends that the technician should only wear the HoloLens when necessary and up to maximum of 30-45min.

Based on the DAMRC engineers' reflections there is a need to find a smart, non-personal way to log on to the HoloLens as it requires a personal user like a normal computer with windows. It is easy when it is the same user that uses the HoloLens or when a personal account relates to the HoloLens. However, this way it is also possible to access mail and calendar, etc. for that account. After using the HoloLens for some time, hand gesturing becomes easier to understand. However, when first trying out the HoloLens, it may be challenging to understand how to press the bottom and make various selections. It is important to consider how to instruct users on hand gestures and general navigation using the HoloLens, to make the experience as user-friendly as possible.

The bone connectivity system "Mobilus mobiWAN" supplied with the Trible HoloLens XR10 system provides excellent sound for both the technician and the expert on MS Teams. However, the system can put a significant amount of strain on the back of the technician's head when the two speakers are mounted on the safety helmet as they should be. One of the the DAMRC engineer personally found that wearing the HoloLens with the speakers mounted became uncomfortable after less than 15 minutes of use, and that he had to take a break. Over time, the length of time before discomfort set in decreased to 10-15 minutes. When the speakers were removed from their mounting position, the strain on the head was reduced and the comfort of wearing the HoloLens increased, allowing for longer continuous use. However, after the speakers were removed, the mobiWAN solution's controller was positioned in such a way that it still put some strain on the user's back head, although not to the same level as the speakers. Nevertheless, the strain was still noticeable and uncomfortable.

The Remote Assist app has improved navigation, with "air tapping" being easier to perform compared to other introduction apps. However, the startup of the app is a little strange and

may require a support video to be shown to the user on how to get started. The startup time of the app is also a little long. Once the app is initialized, calling the Expert at DAMRC is easy, and the Technician only needs to talk and point with their fingers to validate if the correct equipment is taken. The Expert can guide the Technician through assembling the Modal TapTest equipment using voice and augmented arrows. However, it may not be the most efficient method, and videos of the different assembly steps could be made to complement the voice and arrow instructions. When the Expert places an arrow for a specific piece of hardware, the Technician must hold the HoloLens still and pointed towards the hardware. Moving around can make it hard for the Expert to precisely place the arrows and other augmented features. The PC screen of the Modal TapTest equipment is hard to see due to the lack of zooming, and either the Expert needs to mimic the complete TapTest setup menu or have remote access to the PC to interpret the stability lobe or harmonizer results, and also allow the Technician to take a break from the HoloLens.

12.1.2 Second usability test by DAMRC

Based on one of the DAMRC engineers' reflections, it appears that using wireless headphones with HoloLens offers a better experience compared to using the mobiWAN bone connect. The sound quality was clear, but there were some issues with sound volume fluctuations. The TapTest PC cannot currently be included in the Remote Assist Teams call, and the expert may have trouble guiding the technician due to the poor image quality displayed on the HoloLens. The team call experienced issues with both Wi-Fi and mobile internet connections, affecting the quality of the call. Using Remote Assist was found to be easy, but the technician may have trouble distinguishing colours in the call. Additionally, TapTest and HoloLens were found to complement each other.

One of the DAMRC engineers reported that connecting different sound sources using the HoloLens was easy, as it was done through Bluetooth connections set up via the Settings app. Tests were conducted using Marshall ear pods, similar to Apple ear pods. The sound received by the Expert from the Technician was reported to be okay. However, there were no machines running in the background so it cannot be guaranteed that the noise cancellation could be a problem.

13 Conclusion

After the realization of the test in different companies and internally at DAMRC many conclusions can be concluded.

Firstly, as a positive aspect Taptest results were a success. The process itself was a success at both, Vald. Birn, Hein, Sønner and at EasyPartz. Indeed, the provided tap test data based on the test was stable and relevant stability lobes were identified. The use of remote assistance was also partly a success, the engineer was able to guide the user through the whole process, observe the setups and solve issues, secondly even though the tests in general were good there were some challenges when performing them, one of the users expressed some concerns about the interface of the HoloLens, this included some difficulties in navigating through the setting or the interruptions of the video player therefore, a more user-friendly interface will be desired, also all users commented that the HoloLens cut be uncomfortable

when wearing it for a longer period and one of them had some calibration difficulties when used with his glasses. There was also problem with placing the helping arrows precisely enough on the screen on the HoloLens in some of the test, so the user of the hololense could not use the guidance from the DAMRC engineer in at least one of the tests. One of the users commented that the preparation time for the material might be excessive, as a request to have a quick guide of the training materials should be more streamlined and efficient. In terms of technical improvements of screen sharing, due to the poor quality provided though the HoloLens the addition of screen sharing software was identified as a positive improvement, providing a clearer understanding of the TapTest software on the tap test computer that the test person was using, and offering a live view of data collection. From the feedback we obtain that video connection and sound quality may need some improvement.

For the future use of the HoloLens quicker guide implementation, more comfort ergonomics and a better interface would be some of the recommendations that need to be investigated. In the end performing tests with people that are unfamiliar with the equipment has provide additional insights into the user-friendliness and effectiveness of the technology.

To sum up, even though there are some areas that need to improve, as well as some challenges to overcome, from the positive feedback and the success of Taptest it can be concluded that the HoloLens have a potential role for the industrial processes, but it also require the user of the HoloLens and the Tap test equipment to use more time on training to get better knowledge of the process, and one day of training maybe to limit as Taptest process take some time to master.

Dissemination:

With the support from the Danish Industry Foundation, Norlys Vækstpulje and Færch foundation this project will have a broad interest in disseminating the results and insights gained from the project activities. Here is a list of dissemination activities performed during the project:

Seminars:
The Hololens and TapTest equipment has been a part of several demonstrations incl. Spånligaen 2022, Seminar for university students in 2022, VTM fair 2023.
The project had a designated spot for DAMRCs technical seminar called “Teknologi & Tendenser” on the 28th November 2023

Physical presence in DAMRC Technologycenter:
DAMRC has had +1.800 guests in our Technologycenter since project start, and several of these visitors have been introduced to the project outcomes from DAMRC host, through display of the remote assistance hardware and flyer present in the Technologycenter.

DAMRCs Social media channels (LinkedIn & Facebook):
The project has been announced on DAMRC channels including logos on the invitation for “Teknologi & Tendenser” –

see post https://www.linkedin.com/feed/update/urn:li:activity:7128052852018585601

Furthermore Færch Foundation visited DAMRC to have a more in-depth interview about our work with the project –

See post https://www.linkedin.com/feed/update/urn:li:activity:7093126861601288193

DAMRCs newsletter:
Project has been part of the newsletters for July 2022 with a focus that the project was started up and May 2023 when a test was finished at Vald. Birn. See newsletter here: https://mailchi.mp/8eec39b1afe3/lxyqwlir1g-20171476?e=[UNIQID]

https://mailchi.mp/3f912ee17a5b/damrc-fortstter-vkstrejsen-og-har-forstrket-sit-team-20202000?e=[UNIQID]

DAMRC website:
A news article was published on DAMRCs website 13th July 2022 – see post: https://www.damrc.dk/de-to-foerste-inkubationsprojekter-igangsat-kvaelstofkoeling-og-fjernassistance/

Furthermore, the project outline is available on DAMRC.com, where the technical report will be available soon. https://www.damrc.dk/damrc/projekter/remote-process-optimization/

Appendix

Appendix A – Checklist

This appendix shows the different checklists needed for doing the TapTest and using the Hololens. The following Table A1 shows what it is in the TapTest. It is important to check if everything is in the suitcase before and after doing the TapTest. This way we are going to ensure that nothing is missing.

Table A1. Checklist of TapTest items.

Equipment / Item		Check
Big suitcase	1. Hololens helmet	☐
	2. Computer charger	☐
	3. Computer	☐
	4. Little suitcase	☐
Little suitcase	5. White USB (Dongle)	☐
	6. Data module – DAQ SIM5	☐
	7. Hammer – Brüel & Kjaer 8206 58964 (20,81 mV/N)	☐
	8. Microphone for Harmonizer system	☐
	9. Accessories	☐
	10. Adhesive and straps	☐
	11. Accessories and tips	☐
	12. Accelerometer case - Accelerometer – 352A21 SN LW400477 MD Accel (10,31 mV/g) - Elastic band - Accelerometer blue cable	☐ ☐ ☐
	13. Blue hammer cable	☐
	14. Cable, adapters and accessories	☐

To be easier to fill this checklist above here there are some photos that show what is inside each suitcase (Figure A1 and Figure A2).

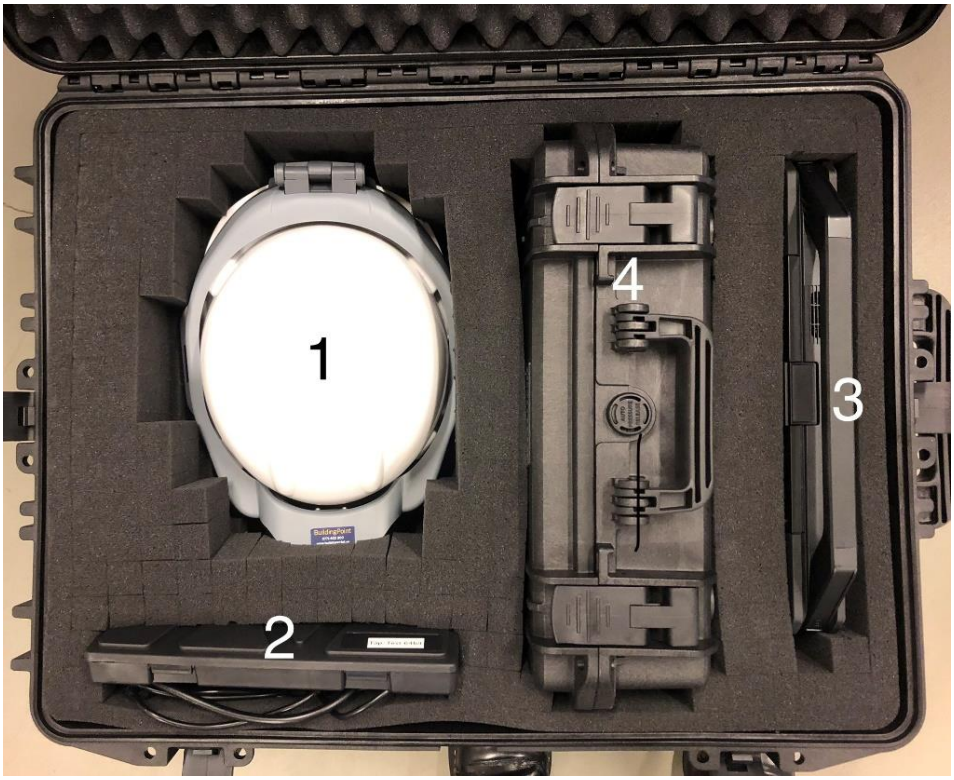

Figure A1. An overview of all the items that need to be inside the big suitcase.

Figure A2. An overview of all the items that need to be inside the little suitcase.

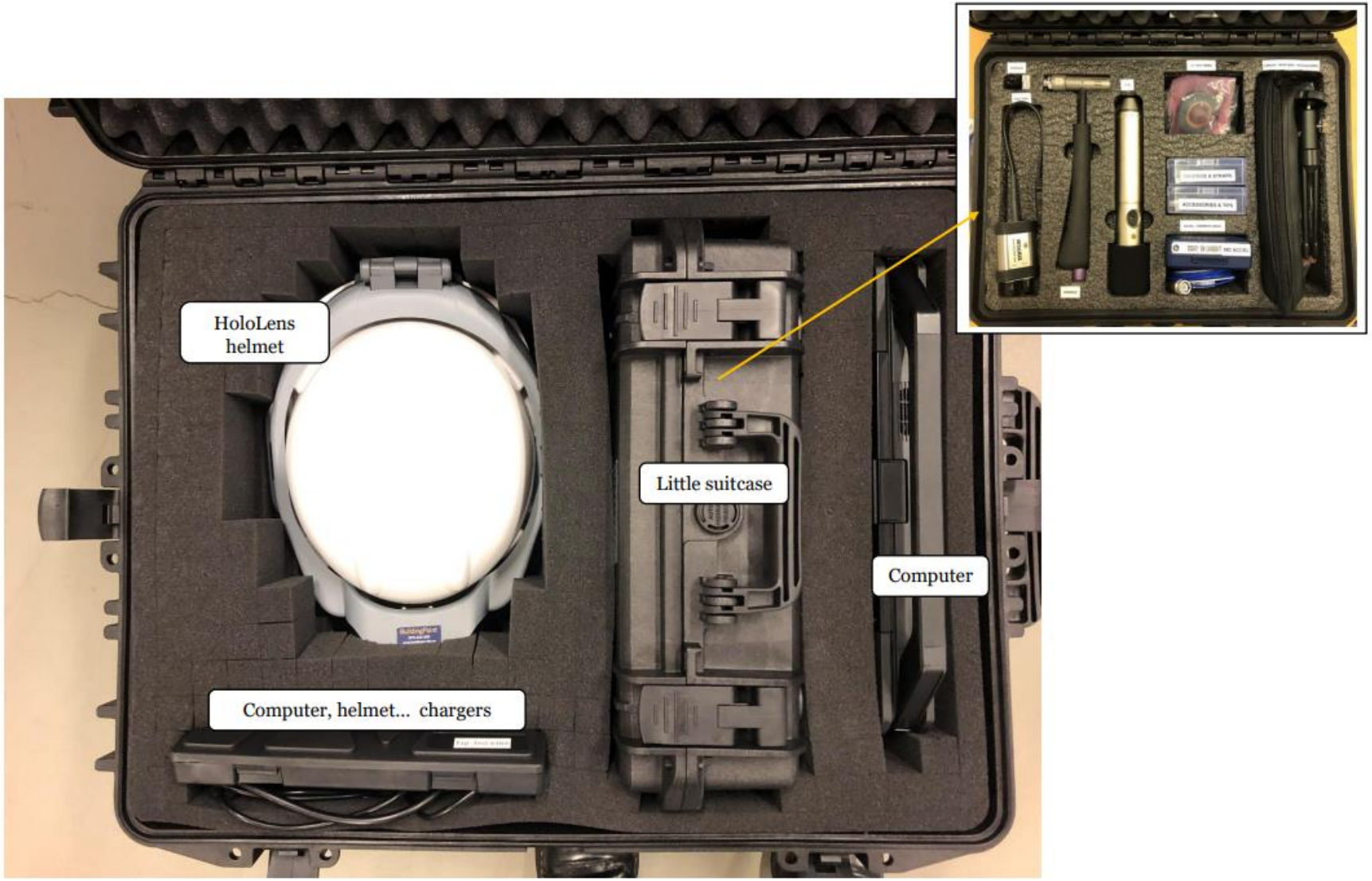

Figure A3. Checklist for the big suitcase for TapTest.

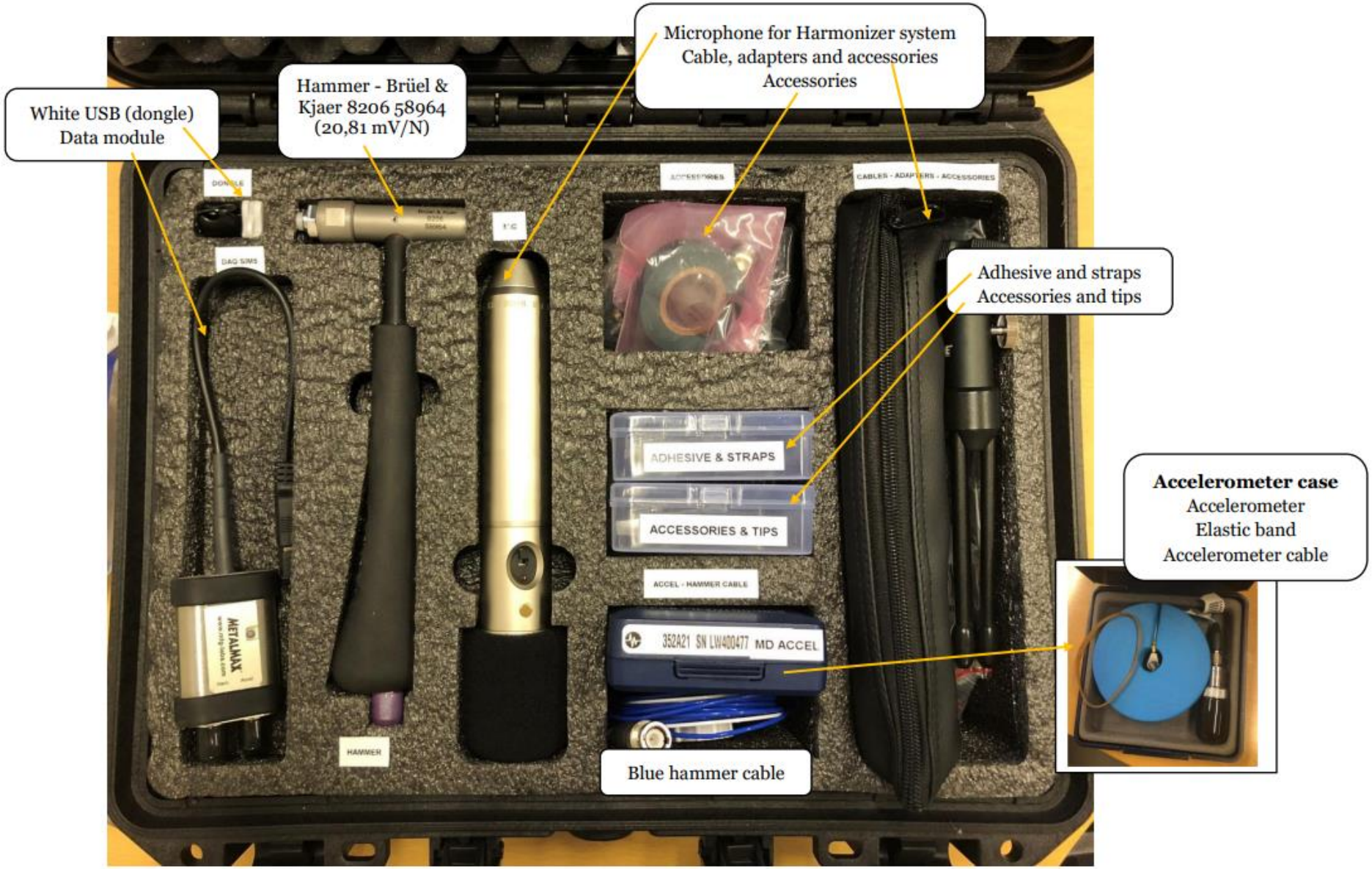

Figure A4. Checklist for the small suitcase for TapTest.

The following checklist (Table A2) needs to be done before DAMRC goes to the company. So the hosting company has to make sure that everything on this list is done before we go there.

Table A2. Before test checklist (companies need to be done before DAMRC goes there).

To do	**Check**
English: Watch HoloLens videos (watch them through the links or scanning the QR codes): Se HoloLens-videoer (se dem via linkene eller scanning af QR-koderne): - 1.1 Udpak og inspicér digital brille / Unzip and inspect the digital glasses (uqualio.com)  - 1.2 Opstart og brug af digital brille / Getting Started and use of digital glasses (uqualio.com)  **Note**: When you open the start menu “Tips” app may not appear in the same place as the video shows. If that happens click to “all the apps” and find the app there. You should open the app from there. Når du åbner startmenuen, vises appen "Tips" muligvis ikke det samme sted, som videoen viser. Hvis det sker, skal du klikke på "alle apps" og finde appen der. Du skal åbne appen derfra - 1.3 Opret internet og øjn kalibrering / Internet connection and Eye calibration (uqualio.com) 	☐

- 1.4 Åbn og brug af fjernassistance app / Open and use of Remote Assist app (uqualio.com) 	
Answer the quiz of each video (it is at the end of each video) Besvar quizzen for hver video (det er i slutningen af hver video)	☐
Internet connection: Ensure that it is proper for the use of HoloLens. - Internet connection must be +100 Mbps - Internetforbindelse: Sørg for, at den er hurtig nok til brug af HoloLens. - Internetforbindelse skal være min +100 Mbps	☐
Check the environment: Ensure that the area is well-lit and free of obstructions. Tjek området: Sørg for, at området er godt oplyst og fri for forhindringer.	☐
Ensure to have everything needed: - A table to place the TapTest equipment - A tool to TapTest it - Wireless ear pods (optional for HoloLens) Sørg for at have alt det nødvendige: - Et bord til at placere TapTest-udstyret - Et værktøj til at TapTest det - Trådløse ørepuder (valgfrit til HoloLens)	☐ ☐ ☐
Fill this survey after DAMRC goes to the company:	☐

Note: Motions sickness:

- The image the user may see is not as clear as it is shown in the introduction videos so a feeling of dizziness may appear, it is very individual when or if you will experience motion sickness.

- So DAMRC recommend only to use the Hololsen for a maximum of 20 minutes.

Bemærk: Motions sickness:

- - Det billede, brugeren kan se når de bruger Hololensen, er ikke så tydeligt, som det er vist i introduktionsvideoerne, så en følelse af svimmelhed kan opstå, det er meget individuelt, hvornår eller om du vil opleve motions sickness.

- - Så DAMRC anbefaler kun at bruge Hololsen i maksimalt 20 minutter.

The following checklist (Table A3) needs to be fulfilled by DAMRC before going to the company.

Table A3. Checklist that DAMRC needs to be done before going to the companies.

Checklist	**Check**
Send the links to watch HoloLens videos	☐
Charge device: Ensure that the HoloLens battery is fully charged before use - Charge helmet - Charge mobilus speakers	☐
Update software: Make sure that the HoloLens software is up-to-date and installed properly	☐
Calibrate device: Calibrate HoloLens device by using the built-in setup tool to align the device's cameras and sensors	☐
Test device: Perform a quick test of the device to ensure it is functioning properly	☐
Fill the TapTest checklist (ensure that everything is well placed)	☐
Take the equipment to the company	☐
Arrange a day with the company to show TapTest and Hololens	☐

Take the survey	☐

Here it is a guideline / checklist to use HoloLens and video call assistance for TapTesting:

Before the video call:

- Charge the HoloLens battery to ensure it lasts the entire video call.
- Ensure that the device is updated to the latest software version.
- Connect the HoloLens to a Wi-Fi network with a stable and fast connection.
- Check the settings on the device to make sure the microphone and camera are enabled.

During the video call:

- Make sure the environment you are in is well-lit to improve video quality.
- Position the device so that you are centred in the camera view.
- Speak clearly and at a moderate volume so that the audio is clear.
- Move slowly and smoothly to avoid shaky video.
- If needed, adjust the camera view by tilting or rotating the device.

After the video call:

- Turn off the device to conserve battery life.
- Disconnect from the Wi-Fi network if not needed for other tasks.
- Store the device in a safe and secure place.

The following Table A4 is an overview of all the sub-instructions needed to guide the user to effectively use the equipment.

These are the aspects that need to be verified before contracting with the companies:

- Internet connection speed
- Willingness to invest the time need to use the equipment – eventually agreement of dedicating one user
- Limitation such that we will only focus on milling operations (per standard, for simplicity)

Table A4. Sub-instructions to guide the user for effective use of the equipment.

General description	**What content**	**What format (paper, video, remote assistance, etc.)**
Introduction letter	Welcome writing	Paper

	What can the equipment be used for? How does it work (briefly)? (+ video walkthrough of equipment and what the purpose of respectively TapTest, Harmonizer & HoloLens are) How much time to allocate?	Paper Paper + video Paper
Ready to use the equipment	Planning and coordination with DAMRC before use To do – before unpacking the equipment To do – unpacking the equipment	Paper Paper Paper
Getting started with MS HoloLens	Unzipping the bag Physical fitting the helmet for the user Power on the HoloLens Log into the HoloLens Connection to Bluetooth sound source Introduction to basic hand gestures	Paper Paper Paper Paper Paper Online guide + interactive app (Tips) Paper

	Connection to internet How to turn sound and brightness up- and down	Paper + Video
Getting started on navigation in the MS Remote Assist	How to open the Remote Assist App How to move the window around (such that is not in the way) How to initiate a call Who to call	Video Video Video + paper Paper
Eventually Supporting videos that can assist voice and arrow assistance	Small videos that document how the equipment is unpacked and assembled?	

Appendix B - Survey

In this appendix it is shown the survey that the companies will need to fill after they have experienced TapTesting and Hololens. It gathers all the necessary information about what has been done well and where we should improve. The aim of this survey is the continuous improvement of these tools and their services. Also with it we want to know how companies experience was with them.

Table B1. Survey for the companies to fill out after using the HoloLens for TapTesting.

RATING YOUR EXPERIENCE WITH HOLOLENS	
At DAMRC we are committed to providing you with the best service in TapTesting with the help of HoloLens. Therefore, we invite you to fill out this survey that will be helpful for us to know what we need to improve. We are very interested in what your comments are. Thank you. From the questions that are asked for a scale from 1 to 5: 1 would be verfu difficult, very unstable… and 5 very easy, very stable…	
Name of the company: Click or tap here to enter text.	**Name of the technician**: Click or tap here to enter text.
Date: Click or tap here to enter text.	
1. How easy was to follow the links and QR codes for uQualio video player? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	
2. How easy was to use uQualio video player? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	
3. How satisfied are you with the user interface of uQualio? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	
4. How would you rate the overall quality of the uQualio video player in terms of. …video and audio playback? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 …functionality? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	
5. Are the videos of how to use HoloLens helpful?	

☐ Yes ☐ No If no, please describe why: Click or tap here to enter text.
6. How easy is to connect HoloLens to Wi-Fi? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
7. How user-friendly do you find the interface of the HoloLens for Taptesting? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
8. What is your experience with the set-up and installation process for using the HoloLens for Taptesting? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
9. How easy is to follow the guides of the video assistance? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
10. Have you noticed any issues or technical problems while using the HoloLens? ☐ Yes ☐ No If yes, please describe here the issues: Click or tap here to enter text.
11. How helpful was the video call assistance during Taptesting with the HoloLens? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
12. How satisfied are you with the video call assistance feature during Taptesting? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
13. How stable was the video during the video call using the HoloLens? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
14. How clear was the audio during the video call using the HoloLens? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
15. How likely are you to recommend the HoloLens for Taptesting to others in your field? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

16. If you have any additional comments, suggestions or recommendations please write here: Click or tap here to enter text.

Vurder din oplevelse med Hololens

Hos DAMRC er vi

Hos DAMRC forsøger vi at give dig den bedste service inden for Taptesting ved hjælp af HoloLens. Derfor inviterer vi dig til at udfylde denne undersøgelse, som vil være nyttig for os til at vide, hvad vi skal forbedre. Vi er meget interesserede i din feedback og eventuelle kommentarer

Af de spørgsmål, der er stillet på en skala fra 1 til 5 er 1 meget svært og 5 meget nemt

Navn på virksomhed: Click or tap here to enter text.	**Navn på tekniker**: Click or tap here to enter text.

Dato: Click or tap here to enter text.

1. Hvor nemt var det at følge links og QR-koder fra uQualios video afspiller?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. Var uQualio nemt at anvende?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3. Var du tilfreds med user interface på Uqualio?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4. Hvordan vil du rate den overordnede kvalitet af video guides på uQ eualio i forhold til Video kvalitet

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Lyd kvalitet?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

5. Var videoerne omkring brugen af Hololens nyttige?

☐ Yes ☐ No

Hvis ikke skriv hvorfor: Click or tap here to enter text.

6. Var det nemt at forbinde Hololens til Wifi? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
7. Fandt du Hololens Brugervenlig I forhold til at bruge det til Taptest? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
8. Var det I din erfaring nemt at opsætte og anvende Hololens til Taptest? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
9. Var det nemt at følge og forstå det personen der guidede dig sagde? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
10. Var der nogle tekniske problemer med Hololens? ☐ Yes ☐ No Hvis der var skriv hvilke: Click or tap here to enter text.
11. Hvor tilfreds er du med kvaliteten af opkaldene da du foretog Taptest? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
12. Var videoopkaldet stabilt da du brugte det på Hololens? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
13. Hvor god var lyden under opkaldet på Hololens? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
14. Vil du anbefale brugen af Hololens og Taptest udstyr til andre teknikere? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
15. Hvis du har nogle ekstra kommentarer eller tanker du vil dele så skriv dem her: Click or tap here to enter text.

Here it is a link to the survey above via google forms:

https://docs.google.com/forms/d/e/1FAIpQLSfJw6kkgybqiyM9_uvzMTDQ_fECA5syivCxU_UtSTjyj2jN1A/viewform?usp=sharing

With this link the survey can be edited and changed, adding more questions or whatever is necessary. Thanks to the google forms template we can gather all the results and put them directly into excel. In this way it will be easier to analyse the results and see where we need to improve.

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