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# Virtual tour of Azipod®

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| Tekijä(t)<br>Otsikko<br><br>Sivumäärä<br>Aika | Aki Koskela<br>Virtuaaliesitys Azipod® propulsorista<br><br>54 sivua + 2 liitettä<br>25.1.2019 |
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| Ohjaaja(t) | Product Support Manager Juha Viitakangas<br>Yliopettaja Jarno Varteva<br>Lehtori Sampsa Kupari |


Tällä hetkellä ei ole dokumentaatiota, joka havainnollistaisi miltä Azipod® ja Azipod huone näyttävät tarkalleen sisältä. Azipod-järjestelmän kokonaiskuvaa on vaikea ymmärtää, koska dokumentaatio ja piirustukset ovat moduulikohtaisia. Lisäksi varsinkin uusille työntekijöille voi olla vaikeaa havainnollistaa mistä mikäkin Azipod propulsorin komponentti löytyy.

Opinnäytetyössä on tavoitteena parantaa Azipod propulsoriin liittyvän dokumentaation visualisuutta ja helppokäyttöisyyttä. Luoda virtuaalinen esitys, jolla on mahdollista havainnollistaa miltä tila näyttää todellisuudessa, mahdollista liikkua paikasta toiseen ja katsoa vapaasti ympärilleen.

Työ toteutetaan luomalla demoesitys Azipod propulsorista ja Azipod huoneesta. Arvioidaan erilaisia virtuaaliesityksien palveluntarjoajia ja skannauslaitteistoja, sekä valitaan niistä paras ratkaisu ABB Marine & Portsin käyttöön.

Opinnäytetyön tuloksina syntyi kaksi tuotetta:

1. Virtuaaliesitys Azipod® propulsorista
   Sisältää pilvipalvelukäyttäjätilin internetselainpohjaiseen virtuaaliesitykseen Azipod propulsorista ja Azipod huoneesta, joka on katsottavissa tietokoneella, tabletilla ja älypuhelimella.
2. VR- esitys Azipod® propulsorista
   Sisältää virtuaalitodellisuusesityksen Azipod propulsorista ja Azipod huoneesta, joka on koettavissa HTC Vive VR -järjestelmällä.

Yleisten mielipiteiden ja kokemusten, sekä ABB Marine & Portsin eri osastojen henkilökunnalle järjestettyjen ryhmähaastatteluiden perusteella voidaan todeta että nämä tuotteet ovat saaneet erittäin hyvää palautetta. Tuotteille on löytynyt monia hyödyllisiä käyttökohteita ja niitä tullaan käyttämään myös jatkossa.



| | |
|---|---|
| Avainsanat | Virtuaalitodellisuus, VR, virtuaaliesitys, 360-kuvaus, 3D-skannaus, Azipod, Matterport |

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Currently there is no documentation that illustrates how Azipod® and Azipod room precisely look like from the inside. It is difficult to understand the overall picture of the whole Azipod system because documentation and drawings are module specific. Also it can be difficult to know where some specific components are located, especially for the new employees.

Therefore, this thesis aims to improve visualisation and ease of access for the documentation related to Azipod. To create a virtual presentation that can provide visually accurate views of how the space is looking like in real life, with a possibility to move and look around in 360 degrees of freedom.

The work will be implemented by creating a demo presentation of Azipod and Azipod room. Evaluate different kinds of virtual tour providers and scanning equipment. Then choose ideal application and equipment for ABB Marine & Ports needs.

As a results of this thesis two products have been created:

1. Virtual Tour of Azipod®
   Includes a cloud account for web browser based virtual presentation of Azipod and Azipod room that can be viewed using computer, tablet or smartphone.
2. Virtual Experience of Azipod®
   Includes immersive virtual reality presentation of Azipod and Azipod room that can be viewed using HTC Vive VR system.

According to general opinion and experience from group interviews made with personnel from different ABB Marine & Ports departments these products have received a very good feedback. Many useful ways of usage has been found for these products and they will be used also in the future.

| | |
|---|---|
| Keywords | Virtual reality, VR, virtual tour, 360 photography, 3D mapping, Azipod, Matterport |

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Helsinki, 25th January 2019

Aki Koskela

## Contents

Abbreviations

1 Introduction 1

1.1 Aim of the thesis 2
1.2 Scope of the thesis 2
1.3 ABB Marine & Ports 2
1.4 Azipod® 3
1.5 Introduction of the chosen vessel to be scanned 7

2 Technologies 9

2.1 Virtual technologies 9
2.2 360° photography 10
2.3 3D scanning 12

3 Research and results 14

3.1 Methodology and sources 14
3.2 Comparisons 15
3.3 Introduction of the chosen Virtual Tour provider 17

4 Scanning report 19

4.1 Scanning order 19
4.2 Points of Interest (POI) 21
4.3 Equipment 22
4.4 Scanning times 32

5 Productisation 35

5.1 Virtual Tour of Azipod® 35
5.2 Virtual Experience of Azipod® 36

6 Possible applications for ABB Marine & Ports 38

6.1 Product Support 38
6.2 Training 39
6.3 Research and Development 40
6.4 Marketing 41
6.5 Spare parts 42
6.6 Production 42

7 Perspectives 44

7.1 2020 vision 44
7.2 Development 45

8 Summary 50

References 51

Attachments
Attachment 1. Camera comparison chart
Attachment 2. Virtual Tour comparison chart

## Abbreviations

| | |
|---|---|
| 2D | *Two Dimensions* |
| 3D | *Three Dimensions* |
| ABB | *Asea Brown Boveri* |
| AIU | *Azipod Interface Unit* |
| AR | *Augmented Reality* |
| AZIPOD | *AZImuthing electric POdded Drive* |
| BOM | *Bill Of Materials* |
| CAD | *Computer Aided Design* |
| CAU | *Cooling Air Unit* |
| DE | *Drive End* |
| DSLR | *Digital Single-Lens Reflex* |
| ECR | *Engine Control Room* |
| HDR | *High Dynamic Range* |
| HMD | *Head-Mounted Display* |
| HPU | *Hydraulic Power Unit* |
| LNG | *Liquefied Natural Gas* |
| MR | *Mixed Reality* |
| NDE | *Non-Drive End* |
| SSU | *Shaft Line Support Unit* |
| OUT | *Oil Treatment Unit* |
| POI | *Points Of Interest* |
| PS | *Port Side* |
| SRU | *Slip Ring Unit* |
| SB | *Starboard Side* |
| VR | *Virtual Reality* |
| XR | *Extended Reality* |

# 1 Introduction

Currently there is no documentation that illustrates how Azipod® (electrical propulsion system) and Azipod room (electrical propulsor system engine room) precisely look like from the inside. Even though there are detailed drawings and 3D models available, the reality can differ quite much from the original design. Projects made before 2013 has only drawings and does not have 3D models. Azipod and Azipod room are places with a difficult access which makes it important to have as good and clear documentation available as possible. Many times when looking for some information it is necessary to try to search photographs taken at the production, commissioning, dry docking or service visits.

Azipod documentation is mostly prepared by ABB, but the actual reality of installations may differ from the original design. For example, Azipod cabling and hose installations vary quite often between different projects. Currently it is difficult to understand the overall picture of the whole Azipod system because documentation and drawings are module specific. Therefore, sometimes understanding how different modules are connected together can be challenging. Also it can be difficult to know where some specific components are located, especially for the new employees.

Azipod rooms, particularly, depict a lot of variability depending on the type of the vessel, owner of the vessel and ship yard where the vessel is built. It is build according to the shape of the vessel and location of other components of the vessel. Usually there is no sufficient layout documentation of Azipod room available. Components and related documentation are provided by different suppliers which means documentation can be found from different locations. The topic contains a wide range of expertise such as virtual reality technology and photography, 360 technology and photography, augmented reality and mixed reality technology, 3D scanning technology, information technology, documentation, mechanical engineering, electrical engineering, automation engineering and naval architecture.

## 1.1 Aim of the thesis

The aim of this thesis is to improve visualisation and ease of access for the documentation related to Azipod®. To implement a virtual presentation that can provide visually accurate views of how the space is looking like in real life, with a possibility to move and look around in 360 degrees of freedom. Possible to include attachments like technical drawings, diagrams, multimedia and other documentation. Presentation that is useful for ABB Marine & Ports personnel from different departments.

## 1.2 Scope of the thesis

The scope of this thesis is to create a demo presentation of selected cruise vessel's Azipod and Azipod room. Demo that shows different kinds of possibilities that can be implemented with the chosen solution. This thesis is evaluating different kinds of virtual tour providing applications and scanning equipment. Choosing the ideal application and equipment for ABB Marine & Ports needs.

Thesis is mainly concentrating on service business unit and product support department, but also other departments are observed. One goal is to implement technologies and equipment that ABB Marine & Ports already has, like HTC Vive virtual reality system and Microsoft HoloLens mixed reality headset. Main focus is on virtual reality, but also other technologies like augmented reality and mixed reality will be observed.

## 1.3 ABB Marine & Ports

This thesis is made for ABB Marine & Ports in Helsinki, that develops electrical and automation solutions for marine industry. Unit is responsible for worldwide marine industry solution development for ABB and has Azipod propulsion unit production. There is also a production factory in Hamina that produces Azipod propulsion steering units. Worldwide ABB's marine business is employing over 2000 people in 22 countries and over 600 people in Finland. Helsinki factory employs over 300 people.

ABB Finland is a strong developer as annually about 200 million euros is invested into research and product development. In the scale of total power output there are over 5000 megawatts of Azipod propulsion systems sold in total. ABB Marine & Ports has service departments also in Miami, Murmansk, Singapore, Shanghai and Lillestrøm. Locations are spread around different time zones for better customer service in 24/7 availability and localisation near customers around the world.

## 1.4 Azipod®

Azipod® (AZImuthing electric POdded Drive) propulsion is a gearless steerable propulsion system. It differs from a regular shaft line propeller system so that the electric drive motor is in a submerged pod outside the ship hull as seen in Figure 1. Azipod propulsion system technology was launched in 1990 and it marked a new era for ship propulsion. Since then, naval architects has inspired to create more efficient and sustainable vessel designs with ABB's Azipod propulsion system. Comparing to a shaft line propulsion, Azipod propulsion systems make vessels significantly more maneuverable and simple to operate, improve hydrodynamics and fuel efficiency by up to 20 percent and save valuable space on board. The name "Azipod" is a registered trademark of ABB Oy. [1; 2]

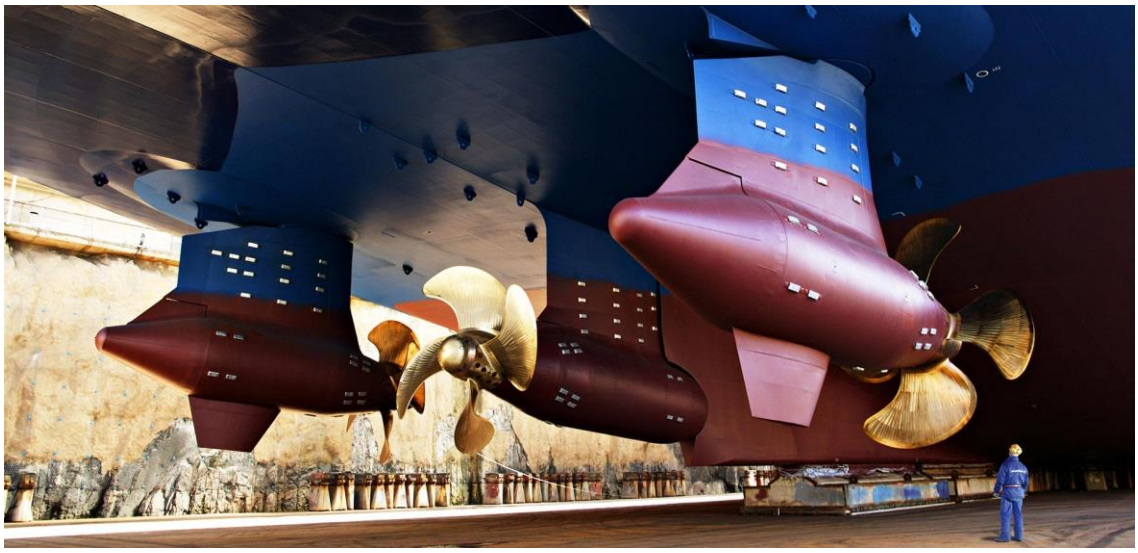

Figure 1: Two Azipod VO propulsion units and Fixipod in the middle [3]

Azipod propulsion system consists of main components that are shown in Figure 2: Section view of Azipod. There is an easy and safe access inside the Azipod for maintenance works.

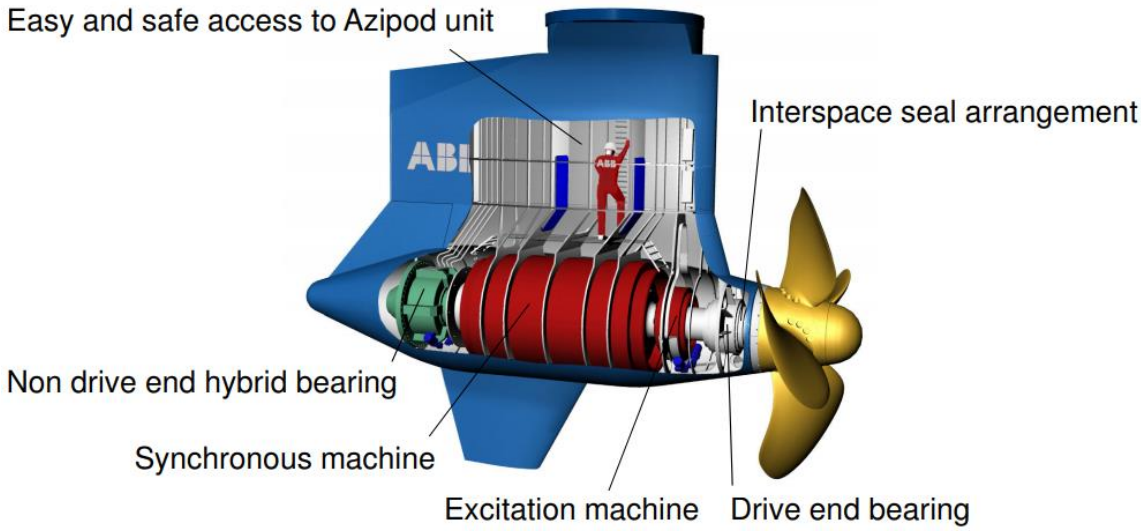


Figure 2: Section view of Azipod [4, p. 7]

The largest Azipod XO propulsion module, propeller included, can weight over 200 000 kilograms. Steering module weights up to 70 000 kilograms. Azipod XO rated output power is from 13 megawatts to 23 megawatts and nominal propeller speed at rated output power is from 122 rounds per minute to 155 rounds per minute. Azipod propulsion units are being used in wide range of vessels from construction vessels to superyachts and drill ships, so they are also suitable for demanding environments. [5, p. 11]

Azipod propulsion units are used in the following vessel types:

- Cruise ships
- Ice going vessels (ice breakers, arctic tankers ja cargo ships)
- Passenger and car ferries
- Yachts
- Exploration vessels
- Maintenance vessels
- Different types of work vessels (wind turbine installation vessels, crane vessels)
- Drill rigs

The Azipod Propulsion Module and the associated Steering Module are fabricated steel constructions. The Steering Module is welded to the ship's hull as a structural member. The submerged Propulsion Module includes a three-phase electric propeller motor in a dry environment, directly driving a fixed-pitch propeller. The propeller is custom-designed by ABB to fit with the ship properties confirmed by the shipyard. The Propulsion Module is bolted to the Steering Module. Each Azipod delivery usually consists of the following fourteen items: two (2) modules and twelve (12) auxiliaries (Figure 3). They are built internally ready for separate deliveries, for shipyard installation, as follows: [6, p. 7]

Azipod-specific delivered items: [6, p. 7]

- Propulsion Module
- Steering Module
- Four (4) Steering Drives (SD-1...4)
- One (1) Electric Steering Control Unit (ESCU)
- One (1) Cooling Air Unit (CAU)
- Two (2) adapting Air Ducts (AD-In), (AD-Out)
- One (1) Slip Ring Unit (SRU)
- One (1) Shaft line Support Unit (SSU)
- One (1) Azipod Interface Unit (AIU)
- One (1) Local Backup Unit (LBU)

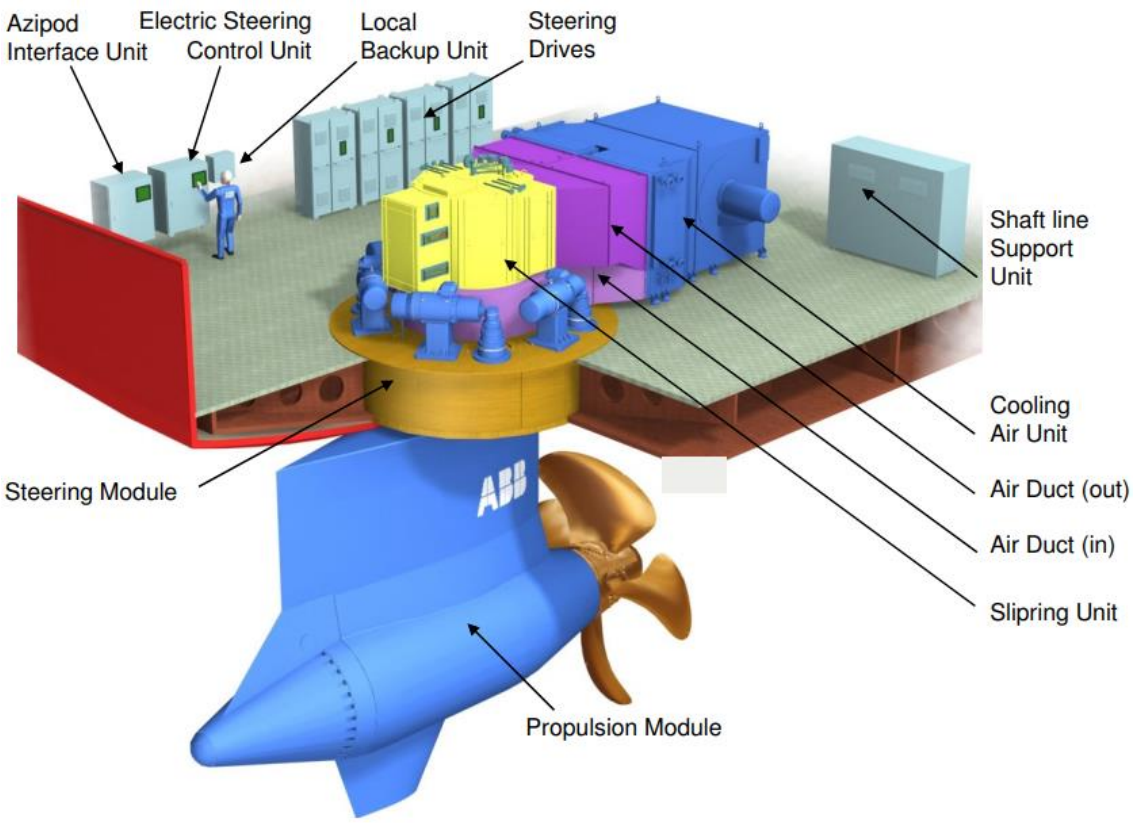


Figure 3: Main components inside Azipod room [7, p. 8]

In order to drive the Azipod propulsion system, the ship needs an electric power plant. Generator sets supply power to the 50 or 60 Hz installation of electric switchboards for distribution to all consumers onboard, including Azipod propulsion. The full ship system consists of the required number of Azipod steering units, plus the delivery of an PWM type marine Propulsion Power Drive per each Azipod. Additionally, propulsion supply transformers (if needed), a remote control system, and the power plant (generators, switchboards and transformers) are usually included in the scope of the delivery. [8, p. 4-6]

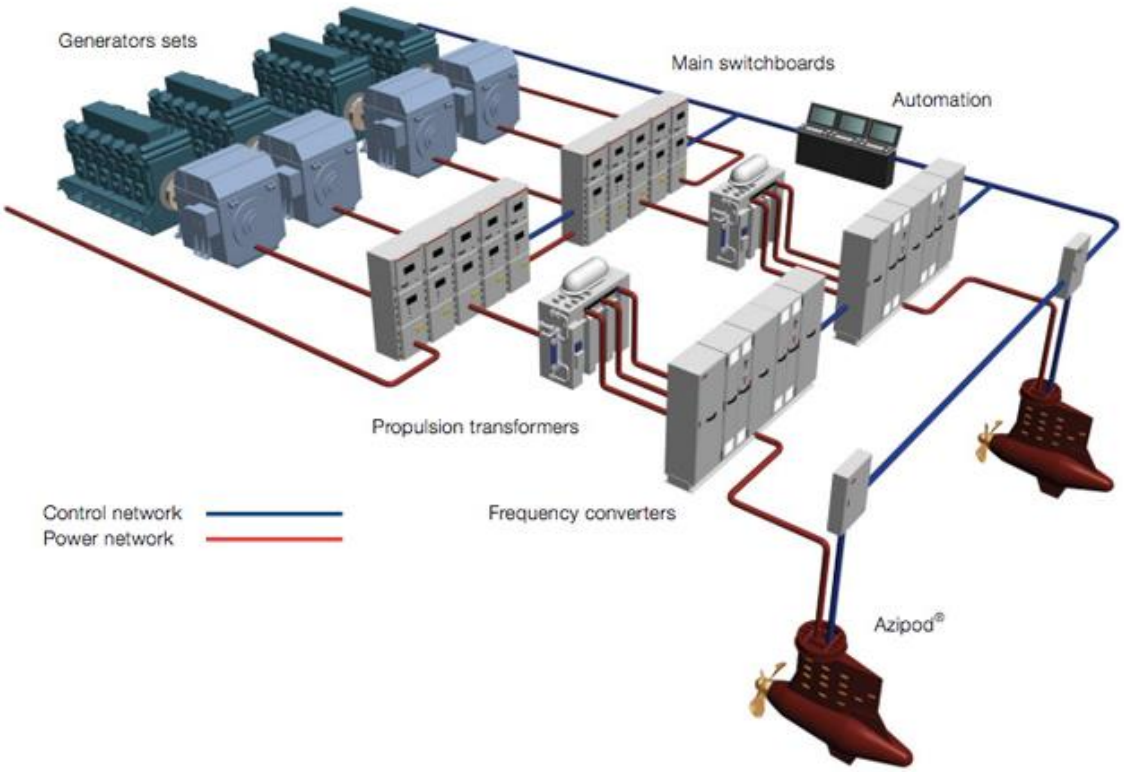


Figure 4: Simplified single line diagram of the power plant with a propulsion system [9, p. 6]

Generally, ABB aims to deliver both the power plant as well as the Azipod system. Mechanical interface to the engine maker is basically standard, although dependent on the delivery of engines or e.g. gas turbines from the contractors. The basic tool for power plant design is the so-called single-line diagram as shown in Figure 4: Simplified single line diagram of the power plant with a propulsion system. The actual onboard configuration can be efficiently discussed already in the early stages of design by using this clear visual representation. [9, p. 6]

## 1.5 Introduction of the chosen vessel to be scanned

*Norwegian Breakaway* was delivered in 2013 from Meyer Werft Papenburg, Germany. She is operated by Norwegian Cruise Line (NCL), and is the first vessel from NCL with Azipod XO electrical propulsion system. This vessel is one of the largest in the world with the weight of 145 655 tons and the length of 323,7 meters. She also has 1657 crew members and is able accommodate up to 3963 passengers. [10; 11]

The innovative *Norwegian Breakaway* reflects the style and vibrancy of her year-round homeport, New York City. In spring and summer she sails from the Big Apple to the pink sand beaches of Bermuda and in winter cruises to the tropical seas of the Caribbean and the Bahamas & Florida. She brings to life the romance and allure of travelling on water with unique spaces like The Waterfront, an industry-first oceanfront promenade lined with alfresco bars and restaurants. Indulge in 29 extraordinary dining experiences, enjoy five multi-storey waterslides in the Aqua Park, and be dazzled by a spectacular firework display on every cruise. She is ideally suited to passengers looking for an entertainment-focused cruise with a wide choice of cuisines on offer. [12]

Figure 5: *Norwegian Breakaway* cruising at New York [12]

*Norwegian Breakaway* was selected as the pilot vessel for the thesis, because I have the most experience working with Azipod XO propulsion units and especially with this vessel. She also happened to have dry docking in a favorable time concerning thesis schedule. Location of the dry docking was relatively near to Finland at Brest, France.

# 2 Technologies

This chapter explains the most important technologies related to the thesis like virtual technologies, 360º photography and 3D scanning.

## 2.1 Virtual technologies

Virtual reality (VR), augmented reality (AR) and mixed reality (MR) are emerging technologies (Figure 6) utilizing a variety of digital (artificial) immersion and overlays on the real world that users can interact with. [13]

**Virtual Reality (VR)** encompasses immersive experiences and content via a VR headset or HMD (head-mounted display). The content is 100% digital and computer generated. Current reality is replaced with a new 3D digital environment in which the user is isolated from the real world. [13]

**Augmented reality (AR)** overlays computer-generated content on top of the real world. This superimposed digital overlay can superficially interact with the environment in real time. AR is primarily experienced via a wearable glass device or through smartphone applications. [13]

**Mixed reality (MR)** combines several technologies into one wearable device. MR lenses or headsets present an overlay of digital content that interacts with objects in the real world in real time. The products are, in most cases, in research and development phase, but MR is viewed through transparent wearable glasses. [13]

**Extended reality (XR)** is an umbrella term that encompasses all real and virtual environments which include VR, AR and MR. [13]

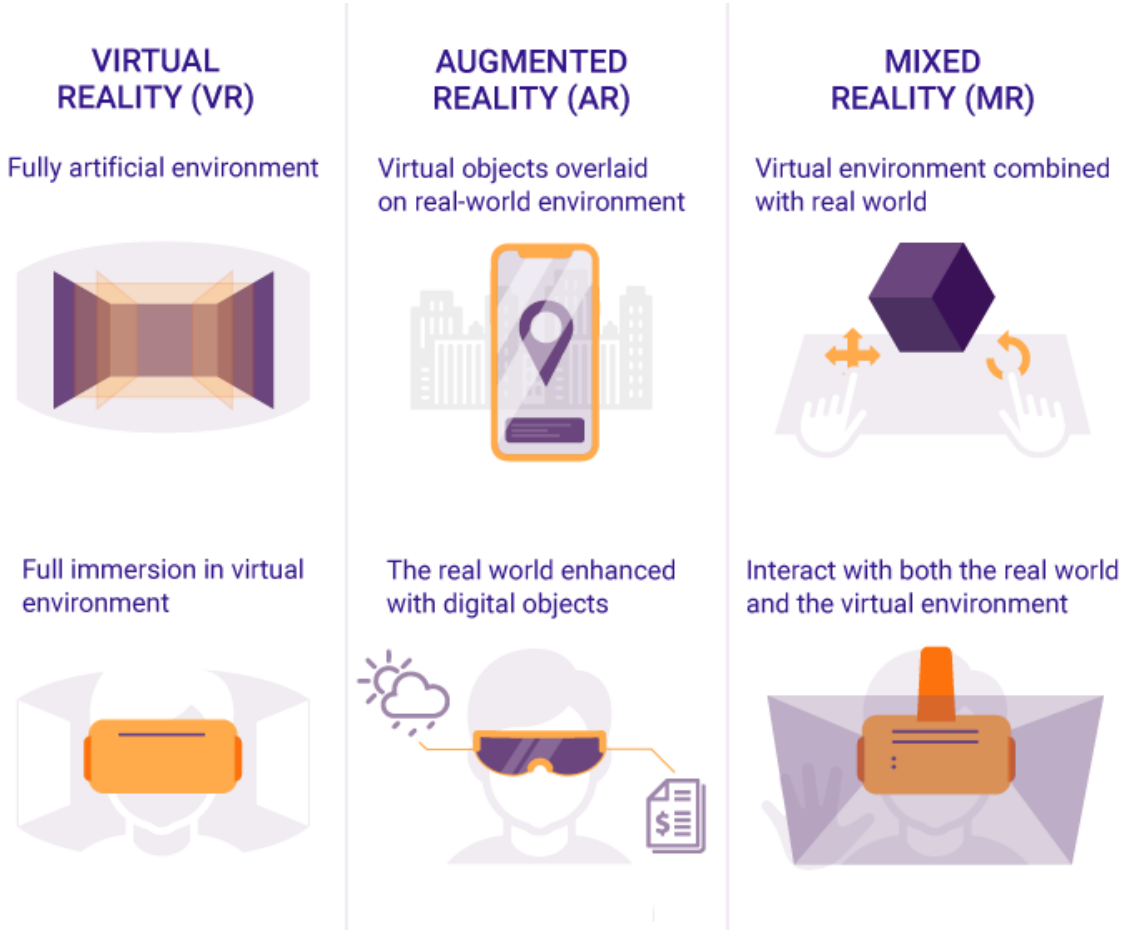


Figure 6: Definition of Virtual Reality, Augmented Reality and Mixed Reality [14]

## 2.2 360° photography

A 360° image is a spherical panorama image with the added element of interactivity. Also referred to as VR (Virtual Reality) photography, virtual tour photography and spherical photography. This technique can capture a location from multiple angles and not only from a single perspective. Using specialized gear, it is possible to create a 360° image of literally any scene, like a bird's eye view from a skyscraper, an erupting volcano, turtles sunbathing in the Galapagos or interior of an Azipod that is about to start moving a cruise ship that weights over 70 000 tons. The purpose of 360° photography is to give the viewer experience as if they were present in the very center of the action. The world of 360° imagery became widely more accessible and popular when Facebook began offering this feature in 2016. [15]

The best and most immersive way to view 360° images is with any VR headset, like Oculus Go, Google Cardboard or HTC Vive. Another way is with a computer with 360° viewing program provided by 360° camera manufacturers or from the internet with 360° photography web sites, like Facebook, Kuula or Veer. Also 360° videos are common within the 360° industry. Basic principle is the same as with 360° photography. [15]

Figure 7: 360° photo before and after stitching [16]

A 360° image consists of several images that are joined together using image stitching software as seen in Figure 7: 360° photo before and after stitching. There are few ways to capture 360° images for stitching, each technique has its strengths and weaknesses: [15]

1. A DSLR (Digital Single-Lens Reflex) camera with a fisheye or wide-angle lens and a panoramic head.
   Strength: best way to get high-quality results.
   Weakness: requires many photos for one 360° image and a lot of post processing. [15]
2. A 360° camera (such as Ricoh Theta V or Insta360 ONE) with two or more fisheye lenses on both sides of the camera.
   Strength: almost no processing required, just point and shoot.
   Weakness: lower image quality compared to DSLR, because consists of less photos. [15]

3. Smartphone with a stitching application.
   Strength: as simple as it gets, no skills or software required.
   Weakness: not as high quality as in the two previous options, plus the need to rotate the phone manually in one spot makes image stitching harder. [15]

The main difference between these options is that the last two do not require specific experience or post-processing skills. The image stitching is performed automatically by the embedded software. This speeds up the workflow but can cause some stitching errors. [15]

## 2.3 3D scanning

3D scanning is a method used to capture the shape of an object or space using a 3D scanner. The result is a 3D file of the object or space which can be saved, edited, and even 3D printed. The most common way to use a 3D scanner is to collect data about objects, environments and people. Each 3D scanning technology comes with its own limitations, advantages and costs. Some 3D scanners can simultaneously collect shape and colour data. A 3D scanned colour surface is called a texture. 3D scans are compatible with Computer Aided Design (CAD) software and also 3D printing after some modification with a CAD software. [17]

Figure 8: 3D scanning with Matterport camera [18]

3D scanning technologies depend on different physical principles and can be sorted in following categories: [17]

- **Laser triangulation 3D scanning technology**, projects a laser beam on a surface and measures the deformation of the laser ray. [17]
- **Structured light 3D scanning technology** measures the deformation of a light pattern on a surface to 3D scan the shape of the surface. [17]
- **Photogrammetry**, also called 3D scan from photographs, reconstructs in 3D a subject from 2D captures with computer vision and computational geometry algorithms. [17]
- **Contact-based 3D scanning technology** relies on the sampling of several points on a surface, measured by the deformation of a probe. [17]
- **Time of flight** 3D scanning technology is based on the time of flight of a laser or IR beam. The laser beam is projected on a surface and collected on a sensor. The time of travel of the laser between its emission and reception gives the surface's geometrical information as illustrated in Figure 8: 3D scanning with Matterport camera. [17]

# 3 Research and results

This chapter describes research methodology and sources, comparisons of additional 360º cameras, Virtual Tour and Virtual Experience providers and introduction of the chosen Virtual Tour providers.

## 3.1 Methodology and sources

Qualitative research was chosen as the main research method since VR, AR and MR are rather new technologies for industrial companies and there is not much literature currently available. Therefore, most of the research was done by searching the latest information from the internet. Also interviews were arranged to review the results of the thesis and to get better insights on how ABB Marine & Ports could implement them in optimal way for different departments. The persons chosen for the qualitative group interviews were managers and specialists from different departments of ABB Marine & Ports, for whom the results of this thesis could be useful for.

There are a lot of interesting articles, forums and Facebook groups from this field. One of the most useful sources of information for this thesis were Facebook groups related to VR and Matterport, where it was possible to gain the most relevant and latest information in daily basis. It happens automatically while normally checking Facebook feeds of friends and other interesting groups that you are subscribed to. To mention few, “Matterport Official User Group (MOUG)” [19], with plenty of useful hints for scanning and equipment from experienced users and Matterport technical support. “VIRTUAL REALITY” [20], with everything related to virtual reality. “Oculus Go” [21], with all the latest information related to Oculus Go. “360 Rumors” [22], for all the latest news, information, tutorials, comparisons and deals for 360° cameras and VR. “HTC VIVE (+PRO) Owners” [23], with all the latest information regarding HTC Vive and HTC Vive Pro VR systems. It is simply possible to find any kind of useful technology group to follow from Facebook. However, it is important to evaluate this information critically, remember that there are many commercial activity in these sources and people might bring out only their point of views.

## 3.2 Comparisons

This chapter describes comparisons between Virtual Tour providers, Virtual Experience providers and additional 360° cameras.

Virtual Tour providers

There are plenty of Virtual Tour providers in the market and here are some of the options considered for Virtual Tour of Azipod: Matterport, Cupix, FeelEstate, 3DVista, InsideMaps, RealVision, Planitar, immoViewer, Marzipano, Kuula and Veer. The main reason Matterport was chosen as the Virtual Tour provider was that no other service could bring as detailed combination of 360° images and 3D model as Matterport. Most of the Virtual Tour providers talk about their solution as 3D tour even though it has nothing to do with 3D as those are simply based on 360° images and moving between those. Therefore, they cannot show or provide any 3D model from their Virtual Tours.

Cupix has an actual 3D model created by 360° photogrammetry. It is possible to add tags and take measurements, but the quality of the 3D model is very low and workflow for creating functional virtual tour is slow compared to Matterport. Therefore, Matterport was the only solution that has 3D mapping and 360° imagery combined in the same solution which makes it the optimal choice.

Attachment 2 [24] in the end of the thesis shows more detailed comparison between Matterport, InsideMaps, RealVision, Planitar and immoViewer. It was released in 7.12.2016 by Paul Collart for we-get-around.com website. So, the information was already a bit outdated, but it was the best and most thorough comparison that could be found, and it gives a good overview of Matterport versus the others.

360º image sharing providers

Some places inside the Azipod are so tight that there is not enough space for Matterport camera to scan the area. That is why a smaller 360º camera, like Ricoh Theta V (Figure 16), is needed and with a compatible 360º image sharing provider those 360º images can be included into Matterport virtual tour by adding them into a MatterTag. 3D model

of the virtual tour is not extended with 360º images though, as these images do not provide 3D mapped data. Some of the 360º image sharing providers compatible with Matterport virtual tour are Kuula, Momento360, Vizor and 360 Panorama.

Virtual Experience providers

Tikab VR Experience [25] was chosen as the Virtual Reality solution provider because at that time it was the only, but very impressive solution, that provided compatibility for 3D files (.obj) exported from Matterport space called MatterPak. From these 3D files Tikab VR Experience creates a virtual environment that user is possible to experience by HTC Vive VR system. This application is based on Unity technology.

It is possible to move freely inside the virtual space, measure dimensions, add 3D objects and more. It is also possible to request more custom features as this solution is still in development. Also similar and more advanced virtual reality environment, Design Space [26] from 3D Talo, that was later discovered, is going to be considered in the future.

Additional 360° cameras

360° camera options

- Ricoh Theta V
- Insta360 One
- Xiaomi Mi Sphere

Ricoh Theta V (Figure 16) was chosen as the additional 360° camera because it was the best compact 360° camera at that time in the beginning of 2018. It had the fastest workflow and 360° image processing time with the best picture quality when shooting in dark. Attachment 1 shows the comparison chart between 360° cameras. Also 360 Rumors has made a very useful 360° camera comparison chart [27].

### 3.3 Introduction of the chosen Virtual Tour provider

This chapter introduces the chosen Virtual Tour provider Matterport and 360º image sharing provider Kuula.

Matterport

Matterport camera is a tripod-mounted 3D camera that uses PrimeSense 3D mapping technology. The same as used for example in Xbox gaming consoles Kinect motion sensing input device. The camera system rotates in place 360° while scanning and transfers the data via Wi-Fi to the Capture app on an iPad in 30 seconds. Capture app is also used for visualising the scanning progress and editing scans instantly. The distance between scanning locations are usually within one to three meters, and the Capture app stitches transferred scans together automatically. Captured spaces are uploaded to Matterport's cloud service for more complete and detailed post-processing. [28, p. 7]

Figure 9: Matterport camera [29]

The Matterport cloud creates a virtual tour that combines high dynamic range (HDR) 360° images in 4K resolution and 3D depth data. The accuracy of 3D model is generally accurate to within 1% of reality under normal operating conditions. For instance, in a

three meters long room, measurements can vary within three centimeters from actual. Furthermore, users can view the virtual tour through their web browsers. It is possible to move through the space, look around in 360 degrees of freedom and then change to a dollhouse or floor plan view of the model. The virtual reality (VR) scene can be experienced by using VR platforms like Oculus Go, Google Cardboard or Samsung Gear VR headset. In addition, coloured 3D mesh file (.obj) and point cloud (.xyz) of the scanned space are downloadable from the Matterport cloud service. [30]

Matterport was chosen as the virtual tour and scanning solution because while doing the research for the thesis there simply was no competitors in the market that could provide even near as good solution. Competitors are lacking the combination of 3D-mapped data and 360° images. There has been an attempt to replicate Matterport's technology by another company, but it ended up with a lawsuit. More about the reasons and other virtual tour providers can be found from chapter 3.2 Comparisons.

Kuula

Kuula [31] is a web-based 360º / VR image sharing community that is compatible with Matterport virtual tour. With Kuula it is possible to include additional 360º images, taken with any 360º camera, into Matterport virtual tour by adding them into a MatterTag. Kuula was chosen as the additional 360º image provider because it had the best overall features from 360º photo sharing providers compatible with Matterport and 360º images taken with Ricoh Theta V.

# 4 Scanning report

This chapter describes the Matterport scans performed at *Norwegian Breakaway* dry docking in Brest, France on 29.4. - 1.5.2018 and during service visits in Helsinki, Finland on 4.6.2018, 13.6.2018 and 28.6.2018.

## 4.1 Scanning order

Azipod

Scanning inside the Azipod with Matterport camera is a challenging and time-consuming effort which means it is important to plan the scanning process thoroughly in advance. While scanning at *Norwegian Breakaway* there was no precise plan where to start and end the scanning process. Instead, scanning was performed by experimentation and adjusting schedule to other maintenance tasks. Sometimes there were also other workers inside the Azipod performing maintenance tasks, so it was important to schedule these tasks collaboratively.

At drive end (DE) of Azipod, due to the narrowest working environment, it is necessary to have another person helping with moving and adjusting rather heavy Matterport camera in place from one scan spot to another. One person on top and one person under the camera. It is important not to have any people appearing in the scans and to not change anything from the space being scanned to keep the professional look and result of the final product. It is possible to move some components if necessary, but if too much have changed compared to previous scans then Matterport CaptureApp cannot align these scans together and rescanning of the failed scan is necessary. One example is to open a door temporarily to continue scanning in another room, but all doors from spaces wanted to be scanned should be left open.

While scanning, Matterport space can be divided into different floors. Each floor has its own floor plan view that can be inspected individually in Virtual Tour of Azipod. According to gained experience from these scans, the ideal scanning order and separating scans on different floors would be as listed below and as shown in Figure 10: Azipod scanning order and floors.

Floor 1

1. Non-drive end (NDE) area
2. Midway floor
3. Drive end (DE) area
4. Midway ladder to half way

Floor 2

5. Midway ladder upper part and swivel stage
6. Steering inner foundation
7. Cooling channel
8. Steering outer foundation (bottom stage of Azipod room)

Floor 3

9. Azipod room

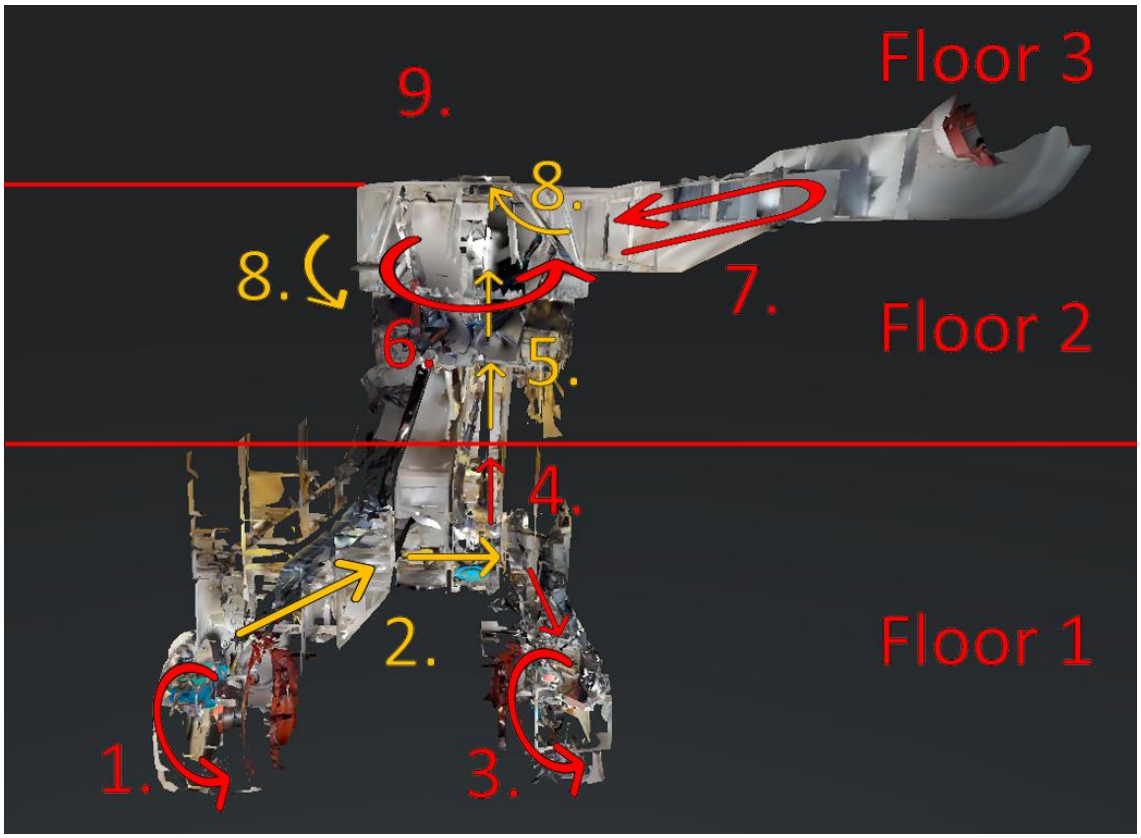


Figure 10: Azipod scanning order and floors

It is recommended to start scanning from the floor 1 and then go higher by Matterport instructions [32]. It is also easier to start adding scans to floor 1 instead of for example floor 3. However, it is also possible to start scanning from Azipod room, floor 3, if maintenance tasks or other factors prevent starting from the bottom of the Azipod. It is good to remember that the space must be scanned linearly, meaning that it is not possible to start scanning at NDE and then continue at Azipod room. Scans must be taken one next to another and distance between scans in tight areas can vary from 30 centimeters to one meter. Matterport CaptureApp does assist through the whole scanning process and does not accept scans that are too far apart and therefore not possible to be aligned together.

Azipod room

While scanning Azipod room it does not matter where to start or end the scanning. It is important to scan all the main components and areas between those. *Norwegian Breakaway* Azipod room is in one floor, but some Azipod rooms do have multiple stages or floors which should be separated to different floors. Distance between scans can vary from half a meter to three meters.

## 4.2 Points of Interest (POI)

Below are listed the points of interest to be scanned from Azipod and Azipod room as well as which camera to be used.

Azipod

- Matterport
  1. All main components and areas between those where camera fits

- Ricoh Theta V
  1. Interspace
     a. Pressure and temperature sensors
     b. Water seal connectors
     c. Heat exchangers at bottom

    d. DE bearing outer sealing connectors
2. Under DE bearing inner sealing connectors
3. Under NDE bearing inner sealing connectors
4. Shaft line turning hydraulic motor
5. Shaft line brake calipers
6. Shaft seal chamber tanks
7. Slewing sealing automatic greasing unit

<u>Azipod Room</u>

- Matterport
    1. All main components and areas between those
        a. Azipod
        b. Steering module
        c. Cooling Air Unit (CAU)
            i. CAU front inside
            ii. CAU mid inside
        d. Adapting Air Ducts (AD-In), (AD-Out)?
        e. Slip Ring Unit (SRU)
        f. Azipod Interface Unit (AIU)
        g. Electric Steering Control Unit (ESCU)
        h. Shaft line Support Unit (SSU)
        i. Steering Drives (SD)
        j. Local Backup Unit (LBU)
        k. Converter room

- Ricoh Theta V
    1. Not needed

### 4.3 Equipment

A great amount of the research time was used for finding and testing suitable additional scanning equipment like additional work lights, support arms, clamps, tripods, mono-pods, iPad covers etc. Below are listed the equipment used for Matterport scans at *Norwegian Breakaway* cruise vessel.

Camera

- Matterport Pro2 3D Camera MC250

Matterport camera (Figure 9) is used for the scanning. It produces both 360° images and 3D mapped data. More details about the camera in chapter 3.3 Introduction of the chosen Virtual Tour provider.

Case for Matterport camera

- MSP outdoor case 5000 for Matterport

Figure 11: Case for Matterport camera [33]

A case for Matterport camera is needed to safely store and transport the camera. It is also possible to store other accessories as shown in Figure 11. Accessories like charger, iPad, small 360° camera with monopod and Gorillapod.

iPad

- iPad Pro 9.7” 32 Gb WiFi + Cellular, Model A1674

An iPad is needed to capture scans with Matterport camera and only iPad is compatible to be used. Matterport CaptureApp application is needed for scanning, editing and sending scans to Matterport Cloud post processing. An iPad with more than 128 Gb of internal memory is recommended to be able to store more and larger spaces. Exporting the scanned raw data is not possible, which means all raw data needs to be stored in iPad.

Case for iPad

- Waterproof case with strap for iPad Pro 9,7”

Waterproof case with strap for iPad is needed due to difficult access scanning environment. It enables easier handling and protection for iPad. Some of the iPad buttons are more difficult to use with the case though.

Tripod for Matterport camera

- Benro A2980T Tripod
- Benro B2 Ballhead with quick mount adapter

Figure 12: Tripod with Matterport camera used in Azipod room (left) and inside Azipod (right)

Tripod (Figure 12) was used for scans in Azipod room and converter room. It was easy and fast to move it from one place to another. Azipod room was relatively fast to scan in general. Tripod was also tested inside Azipod, but it was more convenient to use wall mounted arm instead.

Wall mounted arm for Matterport camera

- Manfrotto 143RC Magic arm
- Avenger D250 gag gobo grip head
- Cardellini End Jaw clamp long 3E

Figure 13: Wall mounted arm with Matterport camera used inside the Azipod

Wall mounted arm was used for scans inside the Azipod. As it is a very difficult environment for scanning, this set was the best way to attach camera in place and adjust to optimal scanning positions as can be seen in Figure 13. It also takes the most time to set up from one scanning location to another.

Magnetic monopod for Matterport camera

- Matthews BH-30 Ball head
- Matthews Magic riser
- Rigwheels - MAG-Tight - RigMount 100 - Heavy Duty Magnetic Camera Mount

Figure 14: Magnet stand with monopod and ball head. On right with Matterport camera.

Magnetic monopod (Figure 14) was used for scans inside the Azipod with even and easier access places like midway floor (Figure 10). It was possible to move camera fast from one place to another and it does not take much floor space like tripod. Also, height of the monopod was optimal for scanning inside Azipod. Magnetic monopod was also used for some of the scans in Azipod rooms steering area under the grid floor (Figure 12).

Magnetic ball head for Matterport camera

- Matthews BH-30 Ball head
- Rigwheels - MAG-Tight - RigMount 100 - Heavy Duty Magnetic Camera Mount

Figure 15: Magnet stand with ball head

Magnetic ball head (Figure 15) was used for some of the tightest places where Matterport camera was possible to be placed inside the Azipod. In places like on top and under the NDE bearing. Non-magnetic surfaces were more challenging with this stand.

Small 360° camera

- 360 camera
  - Ricoh Theta V
- Monopod
  - Selfiemaker Smart
- Tripod
  - Joby Gorillapod, magnetic

Figure 16: Ricoh Theta V with monopod and Gorillapod (left) and with Gorillapod (right)

Small 360° camera (Figure 16) was used as an additional camera for places where Matterport camera, due to its large size, could not fit or did not reach. Ricoh Theta V was mostly used with Gorillapod only, because that way it was easy to fit into small places. Gorillapod magnetic adjustable legs made it possible to attach the camera almost anywhere inside the Azipod. Also, sideways or upside down.

Additional work light

- Godox LED Video Light 120C with two rechargeable batteries
- GoPro PRO-Mounts Camera Adapter
- GoPro PRO-Mounts Front & Side Mount

Figure 17: Godox 120C light mounted on top (left) and bottom front (right) of Matterport camera

Godox 120C light on top of the Matterport camera (Figure 13 and Figure 17) was used in Helsinki at *Norwegian Breakaway* service visits. It is possible to attach light on top or bottom front of the Matterport camera with GoPro PRO-Mounts that are quick to detach. This comes handy inside the Azipod when there is not enough space for the light on top of the camera, it is possible to easily change position to the bottom front of the camera.

Sometimes when using the bottom front position and light was angled too much in front, light was captured in the scan unintentionally. This is not a wanted result, so it is important to always review each scan before moving to next scan position. Light includes two rechargeable batteries. One battery lasts long enough to scan the whole Azipod from the inside when light is turned on only while scanning. This work light spread the light enough to illuminate the whole scanning area and it is possible to adjust light colour temperature and brightness.

Figure 18: Selection of different work light options at Verkkokauppa.com store

There were also many other work light options as shown in Figure 18. Godox 120C was the optimal solution for the usage with Matterport camera due to its size, usability and battery life. It will be used as the main work light in the future.

Additional work light development

MTX tools work light 68 SMD LED on top of the Matterport camera (Figure 19) was used in Brest at *Norwegian Breakaway* dry docking. This work light spread the light enough to illuminate the whole scanning area. It is battery used with a possibility to charge batteries.

Figure 19: MTX tools work light 68 SMD LED on top of the Matterport camera

It was not optimal solution though, as the light was not attached to the camera anyhow resulting it to drop sometimes while scanning due to camera rotating 360 degrees. This can be considered as a safety issue and therefore this work light was not used on top of the Matterport camera after these tests, but it was a good experience for further development.

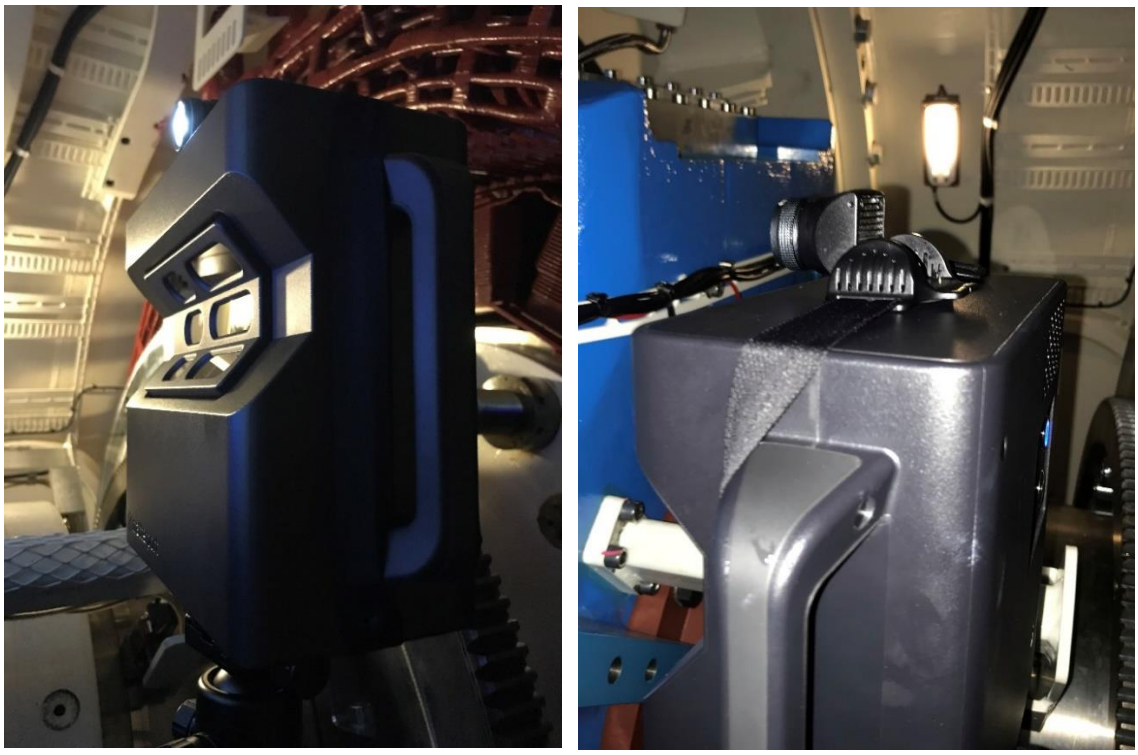

Figure 20: Head light on top of the Matterport camera

Also head light on top of the Matterport camera (Figure 20) was tested earlier with rather bad results. Head light was not spreading light to the whole scanning area leaving outer scan area low light and therefore scans were not accepted by Matterport CaptureApp. Head light as additional work light was not used after this test, but it was also a good experience for further development.

## 4.4 Scanning times

Below are listed the time that was used for scanning of each area and summarised in the end for both Azipod propulsion units and Azipod rooms. This is important information regarding to evaluation of future scanning visits and investments.

Dry-Docking - Brest, France 29.4. - 1.5.2018

PS Azipod 8 h

- Entrance 20 min
- Azipod Mid and NDE 5,5 h
- Steering 2 h

PS Air cooling channels 1 h

- Front 0,5 h
- Middle 0,5 h

PS Azipod room 2 h

- Basic scans 1,5 h
- High scans 0,5 h

PS Azipod room steering 1 h

PS Converter room 20 min

SB Converter room 20 min

I-95 Gangway 1 h

**Total 14 h**

Service visit – Helsinki, Finland 4.6.2018

SB Azipod room 2,5 h

PS Azipod DE 2 h

PS Azipod small 360-cam scans 1 h

**Total 5,5 h**

Service visit – Helsinki, Finland 13.6.2018

SB Azipod center and NDE 3 h

SB Azipod ladder and DE 2 h

**Total 5 h**

Service visit – Helsinki, Finland 28.6.2018

SB Azipod 3,5 h

- DE sides 1 h
- NDE top and bottom, quick 0,5 h
- Steering 2 h

SB Azipod cooling channels (1 h)

- Front 15 min
- Middle – not enough time

SB Azipod room steering 1,5 h

SB Azipod small 360-cam scans 0,5 h

**Total 6 h**

**Summary of all scans**

**PS Azipod 11 h** (Azipod, inner steering, inside cooling, small 360-cam)

**PS Azipod Room 4,5 h** (Azipod room, outer steering, cooling channels, converter room)

**PS total 15,5 h**

**SB Azipod 9 h** (Azipod, inner steering, inside cooling, small 360-cam)

**SB Azipod Room 5,5 h** (Azipod room, outer steering, cooling channels, converter room)

**SB total 14,5 h**

**I-95 Gangway 1 h**

**TOTAL ~30 h**

# 5 Productisation

This chapter introduces the products that has been implemented as the results of this thesis. Virtual Tour of Azipod® and Virtual Experience of Azipod®.

## 5.1 Virtual Tour of Azipod®

Virtual Tour of Azipod® includes a cloud account for web browser based virtual presentation of Azipod and Azipod room (Figure 21) that can be viewed using computer, tablet or smartphone. Offline usage is possible with a Matterport 3D showcase app for tablets and smartphones. Virtual environment is based on 360° images and 3D model captured by Matterport camera and implemented with a cloud account provided by Matterport. It is also possible to view Virtual Tour of Azipod with standalone VR headsets like Oculus Go, Samsung Gear VR and Google Cardboard.

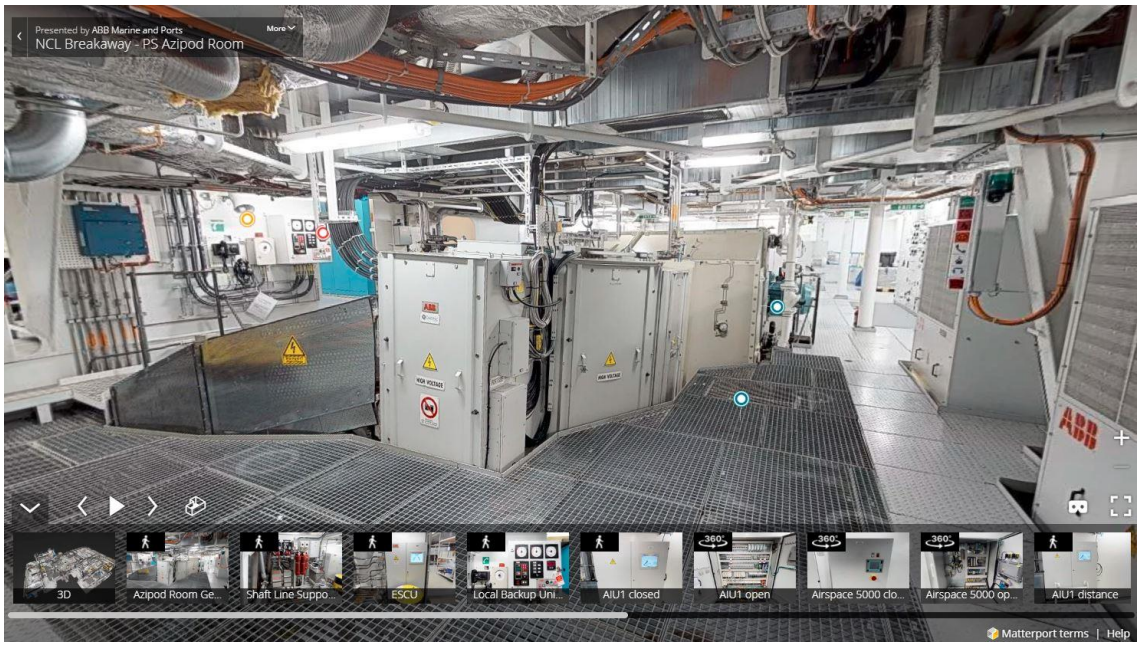


Figure 21: Virtual Tour of Azipod, starting screen of Azipod room [34]

In Virtual Tour of Azipod it is possible to move around with smooth transitions from one scanned 4K high definition 360° image location to another. Look around in 360 degrees of freedom horizontally and 170 degrees vertically. It is possible to zoom and include additional content with tags like text, links, documents, photos, videos, sounds and more. Dollhouse view, that is possible to zoom and rotate, provides useful 3D view of the

scanned environment as shown in Figure 22: Virtual Tour of Azipod, Dollhouse view of Azipod room. Also layout view of the floor and ceiling are available.

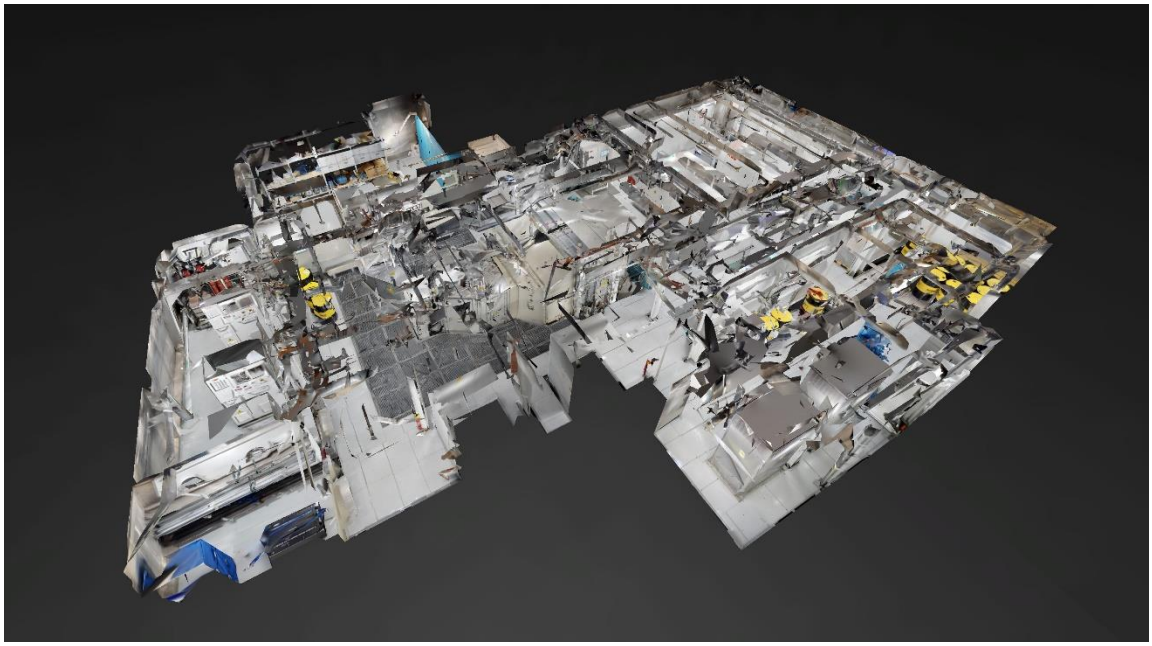

Figure 22: Virtual Tour of Azipod, Dollhouse view of Azipod room [34]

This product can be implemented for multiple purposes like technical support, service visit and dry docking planning, training, engineering, R&D, spare parts sales and marketing which will be discussed more in chapter 6 Possible applications for ABB Marine & Ports.

## 5.2 Virtual Experience of Azipod®

Virtual Experience of Azipod® includes immersive virtual reality (VR) presentation of Azipod and Azipod room that can be experienced by using HTC Vive VR system as can be seen in Figure 23. Virtual environment is based on 3D textured graphics captured by Matterport camera and implemented with Tikab VR Experience application provided by Tikab Strukturmekanik AB.

Figure 23: Virtual Experience of Azipod [25]

In this virtual experience it is possible to move around freely in the 3D scanned virtual environment and look around in any direction by moving your head. It includes an authentic spatial background sound from Azipod and Azipod room that changes when you move from one place to another. It is also possible to take measurements, add 3D models to the virtual environment, interact with the objects and more features will be introduced in the future. This product can be implemented ideally for training, R&D and marketing purposes which will be discussed more in chapter 6 Possible applications for ABB Marine & Ports.

# 6 Possible applications for ABB Marine & Ports

This chapter discusses how Virtual Tour of Azipod and Virtual Experience of Azipod can be implemented for different departments at ABB Marine & Ports. Results are based on the research made for the thesis as well as group and personal interviews made with managers and specialists from each department. Results have been divided for each departments but can also be used for other departments.

Both, Virtual Tour of Azipod and Virtual Experience of Azipod, could be used as a part of each department's familiarisation process for new employees. These products are the best way to familiarise any person with such a difficult access places like Azipod and Azipod room are. This was one of the most popular suggestions that people were mentioning while having the group interviews.

## 6.1 Product Support

Product Support department provides technical assistance for internal customers like warranty, sales, spare parts, engineering, service operations and for external customers like ship crew, ship owners and ship yards.

<u>Service visit and dry docking planning</u>

Virtual Tour of Azipod can be used to inspect and go through upcoming service visits in details with service engineer. It is possible to view needed components inside the Azipod or Azipod room and their working environment beforehand which helps with planning the service visit successfully. It is also possible to take measurements. These factors eliminates possible misunderstandings and clarifies the upcoming service tasks to be performed. This can also be implemented for planning of dry dockings.

<u>Troubleshooting</u>

Just like previously, with Virtual Tour of Azipod, it is possible to check the actual environment and accessibility when troubleshooting a particular component. It is also easier to locate components inside Azipod or Azipod room, as each main component is linked to

the quick links at the bottom part of the screen. By clicking on a components quick link, viewpoint will be changed next to its location and from there it is easy to see the working environment and the location of the component.

It is also possible to add tags to the components in Virtual Tour of Azipod. Tags can include text, documents, photos, videos and more. Adding some necessary documentation to tags like mechanical and electrical drawings, diagrams, spare part lists, work instructions or reference values [35] will make it easier to find necessary documents fast when needed.

Next level task management system

A new kind of task management system could be implemented to Virtual Tour of Azipod. Outsourcing technical inquiries to customer with step-by-step form that customer fills with all the relevant information related to for example new warranty claim, spare part purchase or any other enquiry. All needed information would be specified by ABB Marine & Ports. Currently all ship owners and ship yards have their own templates which sometimes do not have all the relevant information. [35]

## 6.2 Training

Marine Academy department arranges different types of trainings to internal and external customers related to ABB Marine & Ports products. The following citation from Training Industry article describes the benefits of VR training.

> VR may seem like a big departure from traditional learning due to the technology involved. However, there are more similarities than one might think. In fact, VR is a better way to leverage accepted learning principles by, for example, providing the personalized curriculum and insights needed to meet every learner's needs. It can fit into the learning programs of a wide array of companies across numerous industries. [36]
>
> Benefits of Virtual Reality training [36]
>
> - Reduces the cost and time taken to provide training
> - Access to training 24-hours a day, 7 days a week

- Improve learning outcomes and retention
- Generation any number of scenarios such as weather, damage, faults or high risk procedures
- Reduce capital expenditure on physical plant and equipment
- Measure, report and analyse trainee performance and progress

Also, with VR headset user is totally immersed to the content without external disturbing elements. This helps with concentration and learning is more efficient.

Both, Virtual Tour of Azipod and Virtual Experience of Azipod, could be implemented in:

- Azipod space safety training: A safety training that everybody who enters inside the Azipod must first pass.
- Question tags: Hypothetical training that includes different kinds of “What happens if?” questions with few answering options to choose from. [37]
- Production step-by-step tour: Step-by-step tour of different assembly phases of Azipod related assembly works. [35]
- Day as a service engineer: Hypothetical training that includes different kinds of task that ABB service engineer would need to do in a service visit. For example, how to change a filter from Shaft line Support Unit (SSU). [37]
- Azipod technical overviews: Technical overview that goes through technical aspects of Azipod and related components. [35]
- Add instruction videos to tags. Tags are an information window that is possible to be added to a certain point located in the Virtual Tour. [35]
- Module or product-based walkthroughs: Walkthrough animation about components related to certain modules. For instance, water shaft seal -> water shaft seal pump -> water shaft seal tank -> oil circulation hydraulic line -> Shaft Line Support Unit (SSU).

## 6.3 Research and Development

Research and Development (R&D) department innovates new technologies, products, services and systems.

Virtual Experience of Azipod

Virtual Experience of Azipod could be used for testing and evaluating of prototype models of new products in a virtual reality environment. This is a faster and more cost-efficient way for testing space requirements and functionality comparing to a traditional wooden mock-up construction. Many modern companies are already using virtual reality in their R&D process.

## 6.4 Marketing

Marketing department is the face of the company that coordinates and produces materials representing ABB Marine & Ports products globally to the marine industry. The following citation from Digital Doughnut article describes the benefits of VR training in marketing.

> Virtual reality marketing is evolving and it is more important than ever to keep your finger on the trends pulse. When VR takes off, brands and advertisers will be able to reach fully immersed customers on a platform unlike any other. Thus, early adopters will have the upper hand in experience and stand out from other competitors. [38]

Virtual Experience of Azipod

Virtual Experience of Azipod is an ideal solution for marketing usage at marine industry fairs. The quality of the 3D models in the virtual environment is not too detailed, which is good because of possible industrial spying. Another good point is that when using VR headset, the person will only have memories of the experience and it is not possible to take pictures or videos. However, it is possible to show what person with the VR headset is seeing on an addition display.

Virtual Tour of Azipod

Virtual Tour of Azipod might be too high detailed presentation with sensitive material to show at marine industry fairs, but this can be still considered. It is also suitable for marketing of ABB Marine Academy trainings.

## 6.5 Spare parts

Spare parts department arranges needed spare parts and consumables related to ABB Marine & Ports products regarding warranty and service.

Virtual Tour of Azipod

- On board Bill Of Materials (BOM): Customers and ABB employees could view the spare parts lists for needed components from Virtual Tour of Azipod tags [34].
- Virtual shopping tour: Related to previous, customers could also choose and buy needed spare parts from Virtual Tour of Azipod tags [34]. For example, Walmart has been already trying this idea [39].

## 6.6 Production

ABB Marine & Ports production department assembles Azipod propulsion systems. Azipod propulsion units are assembled in Vuosaari factory and Azipod steering units are assembled in Hamina factory.

The following citation from Training Industry article describes the benefits of VR training in production:

> VR provides a training solution aimed at improving employees' safety and well-being
>
> Manufacturing or assembly line training was one of the earliest use cases for VR and continues to be a popular one. This training involves process-focused core competencies, and employees perform intricate tasks in a chaotic and potentially dangerous environment. The stakes are high, the margin for error is slim and there isn't a great method to train other than being on the job. [36]
>
> The key in manufacturing training is to create an authentic learning experience with context where learners are prompted to perform their jobs with all the stressors and chaos they will experience on the job, but in a consequence-free environment. The additional repetitions provided with VR are invaluable, and, more importantly, through adaptive learning, you can identify gaps and hone in on exactly when, where and why employees are making mistakes. Traditionally, training managers have identified these gaps through guesswork and have had to

rely on observation. With VR and adaptive learning, the insights are exact, and prescriptive learning recommendations help fill those gaps and improve performance. [36]

Aside from being a more engaging and fun learning experience, VR provides a training solution aimed at improving employees' safety and well-being. Often, learners are unable to practice (or have repeated practice) in the real-life work environment. VR allows workers to repeatedly train in the exact environment they will be working in without risk of injury. In addition, the immersive, realistic environment of VR has revealed that employees know 20 percent less than what their paper assessments might let on. This insight helps training professionals better understand who is actually ready to work on the floor, diminishing the likelihood of a crucial error. [36]

Production step-by-step tour

Step-by-step virtual tour of different assembly phases in 360º images of different Azipod related assembly works. [35]

Production time lapse 360 video tour

One way to implement 360 videos would be to record time lapse 360º videos of different parts of Azipod production with different steps of assembly line and link those 360º videos together as a 360º video tour with free VeeR 360º video experience service [40]. It would be possible to jump from one 360º video to another just like in Matterport tour. This kind of presentation would be useful for training new employees and also as a marketing material, just like already released YouTube time lapse video "ABB Azipod propulsion unit assembly time lapse".

# 7 Perspectives

This chapter discusses about the future perspectives of the products of this thesis and what can still be developed.

## 7.1 2020 vision

This is the plan how to continue the thesis work and what can be achieved with Virtual Tour of Azipod until the year 2020.

Virtual Tour of Azipod from each Azipod type and size

Virtual Tour of Azipod to be made from each Azipod type and size. It would be beneficial to include as many different kinds of Azipod rooms as possible, because usually different cruise line companies and vessel types have different kind of Azipod room. Some of the Azipod types were left out because of the low number of units manufactured. Therefore, those Azipod propulsion units are not that important in service department's point of view. Some of the Azipod types need to be scanned from Azipod room only, because there is no access inside the Azipod due to smaller physical size of the Azipod.

Azipod types to be scanned with Azipod room included:
Azipod XO2100, XO2300, VO2100, VO2300, VI1600, VI2300S, VI2300L, VI2300 with I4000 steering.

Azipod types to be scanned from Azipod room only:
Azipod ICE 1400, DO1250, CO1250, CZ1400.

Virtual Tour of Azipod from all new-build Azipod propulsion units

Virtual Tour of Azipod to be made from all new-build Azipod propulsion units as a part of delivery and implementation of the scanning process. This will be the easiest to do during the end of commissioning when everything is ready with Azipod and Azipod room. Another option would be to scan the inside of Azipod already in ABB Marine & Ports production and Azipod room later during commissioning, but there is a risk that something

might still change in design during the commissioning phase. Another risk is that earlier scanned model of inside the Azipod would not align with continued scans in commissioning because of different lightning or other changed factors. Therefore, it is better to perform all scans in the same time during commissioning.

Scanning service availability

Trained personnel and needed equipment for scanning of Virtual Tour of Azipod to be available. This means that more people should be trained to perform Matterport scans and all needed equipment should be purchased for successful scanning. This scanning service is needed for previously explained scanning activities, other possible service visit or dry docking planning and for scanning of other ABB products.

## 7.2 Development

3D scanning, 360° photography and virtual reality are still relatively new technologies and getting more popular every day. General interest and investments are very high for the future so there are new releases of more advanced equipment coming for these technologies all the time. Therefore, Virtual Tour of Azipod and Virtual Experience of Azipod may also develop into something totally new and different in the future.

During the research, which included a lot of browsing internet, visiting virtual reality related events and interviews, many interesting ways to further develop this thesis was found and how to implement usage for MatterPak 3D files. There was limited time for making the thesis, so I could not involve everything I wanted. However, here are listed some of the most interesting development ideas.

More scanning locations

This thesis is concentrated mainly on scanning of Azipod and Azipod room. However, there are many other places at cruise ships and other vessel types with ABB delivered components that could also be scanned. Below are listed already scanned locations and some of the perspectives.

Already scanned locations

1. Azipod (inside)
2. Azipod room
3. Converter room
4. Main switchboard
5. I-95 corridor

Perspectives

1. Bridge
    - Control panels and monitors
    - Intelligent Maneuvering Interface (IMI)
    - OCTOPUS – Marine advisory system
2. Breaker room
    - Cyclo cabinets
3. Bow thrusters
    - ABB low voltage motors
4. Mooring deck above Azipod room
    - Azipod related components
5. Engine room
    - ABB generators
6. ECR (Engine Control Room)
    - Control panels and monitors
7. Azipod outside scan in the beginning, during and after dry docking
8. Azipod inside scan before and after each dry docking

<u>Virtual Tour of Azipod production</u>

Virtual Tour of ABB Marine & Ports production facilities in Vuosaari Azipod propulsion unit factory, Hamina Azipod steering unit factory and possibly also Shanghai compact Azipod factory. This could be used as internal training material and possibly external trainings with customers or even as a public presentation to show off how well ABB Marine & Ports production is organised. Similar tour has been implemented already for example, in ABB Motors and Generators Vaasa factory.

Drone scanning

Drone scanning could be used in the future instead of heavy and large Matterport camera. Drones are getting more popular every day and they are being developed constantly. Physical size is getting smaller and features are getting more advanced. Some high-end drones like DJI Mavic Air (Figure 24) feature sensors that scan environment from each side of the drone to automatically avoid collision with obstacles. Even nowadays some of the more advanced drones could be considered for usage inside the Azipod and especially inside Azipod room. It is also possible to have protective structures around drone propellers to prevent collisions and damaging any components.

Figure 24: DJI Mavic Air [41]

Scanning workflow would be much faster as now it is necessary to place and adjust the camera manually in place, which takes a lot of time, especially inside Azipod. With drone, operator would not have to necessarily go inside Azipod at all. However, Matterport does not support any kind of drone scanning yet, but this can be possible in the near future.

Currently it is possible to scan 3D models with drones. This technique is called photogrammetry and it is used mostly for aerial 3D scanning of buildings and landscapes. It is also possible to take 360° photos and videos with drones without the drone showing in the photo or video.

Matterport with Leica BLK360

With Leica BLK360 imaging 3D laser scanner paired with Matterport's 3D reality capture technology, it is possible to achieve better accuracy and further reach for 3D mapping. This means that Leica BLK360 scans can be combined with Matterport camera scans. Further reach of 3D mapping would be useful for scanning large areas like, Azipod production factories or external surfaces of Azipod and ship bottom at dry docking. Leica BLK360 comes with the high price tag of $18 500, but it is also possible to rent. Due to its small size it is easy to carry around as seen in Figure 25: Leica BLK360 imaging 3D laser scanner.

Figure 25: Leica BLK360 imaging 3D laser scanner [42]

Matterport AR

Matterport has announced plans to develop an augmented reality (AR) offering which will allow users to access compelling AR experiences that help people navigate real world spaces, offering them an ability to better understand the highlights and features of a space. Matterport's AR offering will be used across a variety of industries including real estate, property marketing, construction, travel & hospitality, and much more. Combined with Matterport 3D, Matterport AR technology will ultimately bridge the online and on-site worlds together. [43]

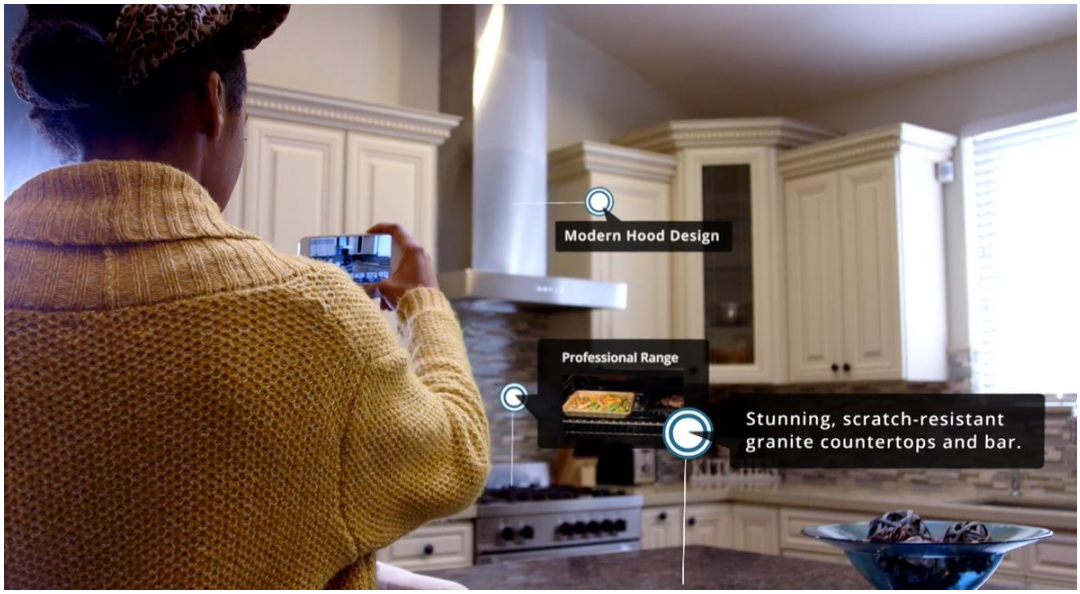


Figure 26: Matterport AR [43]

Matterport AR could also be used for example during service visits. When ABB service engineer goes to Azipod room or inside Azipod, they could easily get the needed data to their smartphone or tablet by scanning the component by Matterport AR and get instruction and technical data from Virtual tour of Azipod tags as shown in Figure 26: Matterport AR.

# 8 Summary

Currently there is no such documentation that would illustrate how Azipod and Azipod room precisely look like from the inside. It is difficult to understand the overall picture of the whole Azipod system because documentation and drawings are module specific. Also it can be difficult to know where some specific components are located, especially for the new employees.

Therefore, this thesis aims to improve visualisation and ease of access for the documentation related to Azipod. To create a presentation that can provide visually accurate views of how the space is looking like in real life, with a possibility to move and look around in 360 degrees of freedom. A presentation that is useful for ABB Marine & Ports personnel from different departments. This will be implemented by creating a demo presentation of Azipod and Azipod room. Evaluate different kinds of virtual tour providers and scanning equipment. Choose ideal application and equipment for ABB Marine & Ports needs.

As a results of this thesis two products have been created:

1. Virtual Tour of Azipod®, that includes a cloud account for web browser based virtual presentation of Azipod and Azipod room that can be viewed using computer, tablet or smartphone.
2. Virtual Experience of Azipod®, that includes immersive virtual reality presentation of Azipod and Azipod room that can be viewed using HTC Vive VR system.

According to general opinion and experience from group interviews made with personnel from different ABB Marine & Ports departments these products have received very good feedback and many useful ways of usage has been found. The usage and further development of these products in the future with ABB Marine & Ports seem very possible and expectations are high, but the actual need will be tested and evaluated.

Some of the near future plans are to create a Virtual Tour of Azipod from each Azipod type and size, all new-build Azipod propulsion units and a scanning service available for any vessel with an Azipod. In general, everything went better than expected, as there was a risk that Azipod would be too challenging environment for creating any kind of virtual tour. Matterport camera size is not optimal to be used inside the Azipod, but with proper camera stand equipment, additional lights and workflow it is possible.

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# Camera comparison chart

Chart 1. Camera comparison chart

| Camera comparison | | | | | | | |
|---|---|---|---|---|---|---|---|
| Camera | **Matterport Pro2 3D Camera MC250** | **PixPlorer 500** | **GoPro 4 + Panohero** | **Panono** | **Ricoh Theta V** | **Insta360 ONE** | **Xiaomi Mi Sphere** |
| Picture | | | | | | | |
| Virtual tour provider | Matterport (only) | FeelEstate / Any | Any | Any | Any | Any | Any |
| Scanning technology | 360 imagery and 3D mapping (IR) | DSLR camera | 360 imagery | 360 imagery | 360 imagery | 360 imagery | 360 imagery |
| Number of cameras | 9 (3 + 3 + 3) | 1 | 1 | 36 fixed-focus cameras | 2 fisheye | 2 fisheye | 2 fisheye |
| 360° image resolution [px] | 134 MP | 32000 x 16000 px (500 MPx) | 72 MP | 16k x 8k 108 MP | 5376 x 2688 12 MP | 6912 x 3456 24 MP | 6912 x 3456 24 MP |
| 360° video resolution | No | No | No | No | 4K 3840 x 1920, 29.97fps | 3840 x 1920, 30fps | 3456 x 1728, 30fps |
| 3D mapping resolution | 10 points per degree (3600 points at equator, 1800 points at meridian, about 4 million points per pano) | No | No | No | No | No | No |
| Storage [GB] | iPad storage | Memory card | Memory card | 16 GB | 19 GB internal | SD card max.128 GB | MicroSD max.128Gt |
| Camera size [mm] | 230 x 260 x 110 mm | 300 x 190 x 130 mm | 41 x 59 x 21/30 mm | Ø110 mm | 130 x 45 x 23 mm | 96 x 36.5 x 25 mm | 78 x 674 x 24 cm |
| Weight [kg] | 3.5 kg | 3.3 kg | 0.1 kg | 0.48 kg | 0.125 kg | 0.082 kg | 0.108 kg |
| Control unit | iPad | Control panel or remote | iOS, Android | iOS, Android | iOS, Android | iOS | iOS, Android |
| Data interface | WiFi | Infrared | WiFi | WiFi | WiFi | Bluetooth | WiFi, Bluetooth |
| 360° rotation needed | Yes | Yes | Yes | No | No | No | No |
| One click 360 scan | Yes | Yes | No | Yes | Yes | Yes | Yes |
| Light included | No | Yes | No | No | No | No | No |
| Possible to attach light | Yes | Yes | No | No | No | No | No |
| Min. object distance | ~100 cm | ~10 cm | ~10 cm | ~100 cm | ~10 cm | ~10 cm | ~10 cm |
| Battery life [h] | 8 h | 7 h | 60 mins | ~100 shots | 300 shots / 80 mins | 70 mins | 75 min with WiFi |
| Battery charce time [h] | 4.5 h | 4 h | 2 h | 4 h | 3 h | 2 h | 2 h |
| Scanning speed [s] | 20 s | 270 s | 50 s | 2 s | 1 s | 1 s | 1 s |
| Prosessing time | Medium | Medium | Slow | Medium | Fast | Medium | Medium |
| Camera price [€] | 3695 | 5000 | 360 | 1495 | 458 | 349.9 | 350.9 |
| Annual Cloud service [€] | 900 | 1188 | No | No | No | No | No |

## Virtual Tour comparison chart

Chart 2. Virtual Tour comparison chart [24]

| | Matterport | InsideMaps | RealVision | Planitar | immoViewer |
|---|---|---|---|---|---|
| **Hardware** | | | | | |
| Estimated hardware investment range | $4,500 - $5,820 | $190 - $810 | $0 - $2,270 | $4,500 - $4,620 | $0 - $399 |
| Uses off-the-shelf camera equipment | N | Y | Y | N | Y |
| **3D Tour Summary for *Palo Alto Eichler*** | | | | | |
| 3D tour cost | $19 | n/a | n/a | n/a | n/a |
| 3D tour + schematic floor plan cost | $55 | $50 | $82 | $70 | n/a |
| Monthly subscription required | Y | N | Y | N | Y |
| Total 3D tour data capture time | 42 min | 24 min | 80 min | 22 min | 24 min |
| Total "Level of Effort" | 62 min | 35 min | 110 min | 52 min | 39 min |
| Amount of data to upload | 0.50 gb | 3.0 gb | 1.5 gb | 0.04 gb | 0.06 gb |
| Upload wait time at 2 Mbps | 0.6 hrs | 2.8 hrs | 1.4 hrs | 0.04 hrs | 0.06 hrs |
| **Capture Process** | | | | | |
| Single scan (panorama) capture | 45 sec | 65 sec | 60 sec | 45 sec | 40 sec |
| Real-time feedback | Y | N | Y | Y | Y |
| Modify camera settings | N | N | Y | Y | Y |
| Outdoor scan (panorama) support | Y | Y | Y | Y | Y |
| Max number scans per listing | 200 | unlimited | unlimited | unlimited | unlimited |
| **Post Capture Administration** | | | | | |
| Availability post-upload | 2-10 hrs | 12-24 hrs | 1-6 hrs | instant | instant |
| Exclude scan (or panorama) | Y | Y | Y | Y | Y |
| Modify imagery within panorama | N | N | Y | Y | Y |
| Information tags | Y | N | N | N | N |
| Agent branding capable | N | Y | Y | Y | Y |
| Service provider (or operator) branding | Y | Y | Y | Y | N |
| Limit horizontal field of view | N | N | N | N | Y |
| Customize tripod cover in panorama | N | N | Y | Y | Y |
| **3D Tour Results** | | | | | |
| Curated tour | Y | N | N | Y | N |
| Hotspots and occlusion | Y | N | N | N | Y |
| Vertical field of view (max=180) | 170° | 120° | 180° | 180° | 180° |
| Zoom into panorama (or scan) | Y | N | N | Y | Y |
| Mobile browser support | Y | Y | Y | Y | Y |
| Branded and unbranded versions | Y | Y | Y | Y | Y |
| Support for multiple floors | Y | Y | Y | Y | Y |
| **3D Tour Navigation** | | | | | |
| Walk via mouse roller | N | N | Y | N | N |
| Walk via keyboard (up & down keys) | Y | Y | Y | N | N |
| Walk via on-screen arrows | N | Y | Y | Y | N |
| Walk via on-screen hotspots | Y | Y | Y | N | Y |
| Walk via floor plan hotspots | Y | Y | Y | Y | Y |
| Walk via highlight reel | Y | Y | Y | N | Y |
| Dynamic floor plan reference | N | Y | Y | Y | Y |
| Minimize floor plan reference | n/a | Y | N | Y | Y |
| Maximize screen with only panorama | Y | Y | N | Y | Y |
| **3D Tour & Virtual Reality** | | | | | |
| VR capable | Y | Y | Y | N | Y |
| Additional charge | Y | N | N | n/a | N |
| Google cardboard support | Y | Y | Y | n/a | Y |
| Samsung Gear VR support | Y | N | N | n/a | Y |
| **Photo Gallery** | | | | | |
| Gallery capable | N | Y | Y | Y | N |
| Extract display-ready (MLS) images from tour | Y | Y | Y | Y | Y |
| Extract print-ready (high-res) from tour | N | Y | Y | Y | N |
| Multiple aspect ratio for stills | N | N | Y | N | Y |
| Import external images to gallery | n/a | N | Y | Y | N |
| **Schematic Floor Plan** | | | | | |
| Schematic floor plan included | N | Y | Y | Y | N |
| Additional cost | $36 | N | N | N | $4 - $40 |
| Customize room labels | Y | Y | N | Y | unknown |
| Support for metric & imperial units | N | Y | N | Y | unknown |
| **3D Tour Sharing Features** | | | | | |
| Embed in other web sites | Y | Y | Y | Y | Y |
| Private 3D tours | N | N | Y | Y | Y |
| Host on own servers | N | N | N | Y | N |
| Password protected option | N | N | Y | N | N |
| Require visitor registration | N | N | N | N | Y |