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Abstract

Visualization technologies are common in industry. But recently, these technologies have found their applications in Petroleum (Oil and Gas) industry.

The Oil and Gas industry constantly strives to increase production and reduce costs. The operational sites and areas are usually quite harsh and extreme environments. The number of skilled workers significantly reduced in industry both due to recent oil price plunge as well as natural ageing of the specialists. In addition, most of the current major capitals currently run considerable number of old assets, which are quite costly to operate and maintain, comparing to modern assets. That said, the industry applies a lot of efforts and resources in order to find new ways to improve operations routines, both methodologically and technologically and according to historical asset data as well as to modern trends.

In current research, in order to find a solution, I decided to elaborate on a topic of Visualization Technologies. Literature review, documentary analysis, media sources overview, industry worker's interviews and, where possible, practical experience with Visualisation related software products were utilized to form up the basis of the research methodology.

The research revealed that some of current asset operation routines or tasks lack complete, discoverable, unambiguous, up-to-date data as well as relevant context, information structure is usually not optimal and its presentation is not intuitive. Also, there are just a few tools and applications supporting shared and inter-discipline collaboration and decision making. That significantly increases operations complexity and thus leads to non-optimal productivity, indecent decisions, inferior situation awareness and higher costs.

Visualisation Technologies here may assist in finding optimal ways or solutions for the aforementioned challenges. Increased demand for oil and gas influences companies to develop Digital Platform, but Visualisation Technologies has moved this development to a new level. Visualisation Technologies facilitate meaningful modernization of the industry, as well as increase of the business value.

Acknowledgments

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I want to honour Visco AS for providing me an interesting and actual topic as a challenge. Many thanks to Øystein Stray, CEO for his advices and material provided.

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Sviatlana Pozniak

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Abbreviations

AR	Augmented Reality
ANNs	Artificial neural networks
DOF	Digital oilfield
ET(V)L	Extraction, Transformation, (Validation), Loading
FDP	Field Development Planning
HSE	Health, Safety and Environment
IO	Integrated Operations
NPT	Non-productive time
OO	Owner Operator
ROV/ROUV	Remotely Operated (Underwater) Vehicle
SA	Situation awareness
SCADA	Supervisory Control and Data Acquisition
MR	Mixed Reality

1 Introduction

Nowadays, life around us is becoming more and more digital. Visualisation Technologies can help us to adapt, to educate and to control in a faster and more secure way. As an ordinary example: almost everyone has seen visual instruction inside an airplane. It is simple, fast, clear and susceptible path to explain required actions in case of emergency. Moreover, inside an airplane we also have the instruction in a paper version. Demonstration and paper version are the visualisation tool. This example shows to us that even if it is a first flight for someone or if the person is not related to aviation, after security demonstration, passengers would earn what to do in a critical situation.

Visualisation has a huge perspective in Oil and Gas industry. First of all, because of increasing overall digitalisation, requirements to reduce the cost and increase the performance, it is possible to use this technology during different phases. Every stage needs a high degree of integration between large number of employees in different sectors of an industry. Functioning usually includes large amount of scattered and specific data.

1.1 Background

Visualisation, in simple words, can be described as translation of environing information into mental image. That helps explain complex ideas simply, because visual way of perceiving information is more convenient and simple for human beings. As Napoléon Bonaparte said: “A good sketch is better than a long speech”. And that is a true. Human brain is operating in a way, that allows to process images quicker than anything else. Images make it easier to pay attention to something important and replace thousands of words. When we see a picture, we know the sense and scenario within it immediately. Rapid image processing evolved through evolutionary development. Our ancestors survived due to the rapid detection of danger and due to the prevention of poisoning because of the understanding in the development of colour in berries. Images contribute to early learning. It's much easier to watch a short film than to read a bare text. Images help to connect emotional components. The person feels involved. Images are an important part of science communication, because it can make sense out of datum.

Oil and Gas are the most important commodities in the word. The industry has become more complex than ever before. This is due to the growing demand for oil and gas, the complication of production conditions, the reduction in the number of skilled workers, tough security regulations, desire to cut costs and improve production rate. New technologies can provide a proper solution to these challenges. Visualisation Technologies here is a bridge between industry complexity, hi-tech innovations and increase of business value.

Business value here can be considered cumulative of various factors. The elements of value are, for example: Quality, Service, Security, etc. Each of those characteristics can influence on business value in different ways. For creating or increasing value, changes in those elements should lead to the "good" for the company (Apostu, 2008)

1.2 Objectives

The mainstream of this thesis is to show the advantages and challenges of appliance of Visualisation Technologies in Oil and Gas industry. The key objectives are:

1. To represent and analyse the current picture of Visualisation Technologies utilization within Oil and Gas industry;
2. Identify the future perspectives of Digital Platform;
3. Consider the basic points in visualisation creation, and its perspective for future.
4. Draw conclusions and suggest future recommendations.

1.3 Methodology

The goal of thesis was to do a literature review of available theory with following analysis on relevant topics for Visualisation Technology. This method helps to consider the Visualisation Technology from different points of view in Oil and Gas industry and identify the main sources for Business value creation. For successful implementation of the method, a large-scale research was initiated by searching and discussing documents concerning relevant topics. Documents were collected from different sources: literature review, documentary analysis, media sources overview, industry worker’s interviews and practical experience with Visualization related software products. The result of this method is a theoretical description of Visualisation artefacts creation for Oil and Gas industry, with its advantages and disadvantages, and theoretical review of future prospects.

1.4 Scope / Limitations

Visualisation Technologies have several manifestations. As per the company requirements, the technology is kept confidential in operational sphere of Oil and Gas industry. Therefore, technology will not be shown in all aspects of the asset life cycle (i.e., Design, Construction, Handover, Commission etc.).

1.5 Motivation

The present topic is highly recent, actual and very practical. There are discoveries that have happened recently. This is highlighted by a large number of articles, webinars and books. Revealed, the Visualisation Technologies today are not being utilized to full extent. Most Owner Operators (OO) today accommodated and persisted huge pile of data about their assets but have no full perspective of what is there. The same for Service Companies, which are usually struggling to provide comprehensive, rigid, cost effective offers to OO's, due to lack of required information or its ambiguous representation. Those pain points could be healed by setting up a Digital Platform, which in turn will enable an easy accomplishment of visual access to Platform/Asset artefacts. That is why the author is keen to elaborate Visualisation Technologies topic within current master thesis.

1.6 Thesis structure

The thesis contains 8 Chapters. Below there are a brief description provided.

Chapter 1 gives a brief introduction to the Thesis objectives and the methods used.

Chapter 2 provides required definitions and notations for further research.

Chapter 3 describes several visual applications in Oil and Gas industry. That overview highlights current situation understanding of Visualisation Technologies used in the industry.

Chapter 4 studies the notion of Digital Oil field, it's dissemination, development and prospects.

Chapter 5 describes the main challenges for Visualisation creation. In addition, this chapter contains the future view of Visualisation Technologies.

Chapters 6, 7 and 8 include discussion about Visualisation Technologies, conclusion for this thesis and recommendations for further research based on Thesis research.

2 Visualisation Technologies prerequisites.

For any technology to work at full capacity, it is required to have a number of prerequisites in place. Visualisation Technologies are heavily relying on variety of technical aspects and business processes to be established upfront. Having them in place will enable further development and application of Visualisation Technologies within Oli and Gas industry. Author is keen to elaborate on those most important and innovative below. Let's start with Visualisation definition.

2.1 Visualisation

"Visualisation is any technique for creating images, diagrams or animations to communicate a message." (Wikipedia, 2017b)

People has been using drawings from the beginning of time. More than a thousand years ago, drawings were used on rocks. Digital Visualisation became a very common tool. This was facilitated by the invention of computer graphics. Now 3D TVs are spreading more and more, Mixed reality (MR), Augmented Reality (AR) and Virtual Reality (VR) are not fiction anymore. In Oil in Gas industry 2D drawings, 3D viewings, video conferences, etc. are commonly used. Since Visualisation Technologies tends to use user-friendly and convenient interface, this greatly facilitates the issue of familiarization, training and further usage.

2.2 Data Management

As it has been stated above, Visualisation is graphical representation of information. Hence, for any Visualisation Technology to operate properly, there need to be a data to feed in. Oil and Gas industry in last 30-40 years collected considerable amount of data concerning its operations. However, in most cases, the shape of that data is quite heterogenous, patchy, incomplete and out of context. Even in cases when information, concerning some specific operations area, is stored in persistent way by means of a business process and/or with aid of some software, it is still just a part of the operations picture as a whole.

According to Data Science, such datum is defined as unstructured or "meaningless", and therefore it is close to impossible to visualise it meaningfully. However, there are certain techniques to aid:

1. **Data Warehousing** is a technique of data aggregation. Information is being pulled from variety of sources, piped through ET(V)L (Extraction, Transformation, Validation, Loading) process and then shaped to desired view; ready for consumption. This approach nowadays deemed old-fashioned and time/resource consuming, yet proved to be very powerful. That is one of the ways to create a data feed for Visualisation Technologies.
2. **Data Lake** is a technique of collocated storage of raw, multi feed data in a schema and volume agnostic way. I must admit, it is not particularly good data feed for Visualisation Technologies, however it facilitates a process of deliberate data collection throughout asset(s) operations. As some conducted interviews suggest, one of the issue is that a lot of historical data were not persisted and thus lost, sometimes preventing maintenance or upgrade plans from happening.
3. **Data Mining** is a very broad definition. Depending on objective outlook, it is a process of information mix and match to make the data comply with certain information standard in order to reveal certain context. The means of data mining are varying from hand crafted data composition to application of Artificial Intelligence analysis/predictive algorithms. That forms up composition of multi-tenant and multi contextual data sources, which serves best as Visualisation Technologies data feeds.

2.3 Connectivity

Proper data collection is possible with below data connectivity/transfer technologies. Advanced network technologies can be used to create more connected, smarter environments, where data is gathered from diverse sources to drive performance gains. There is an overview two of technologies below.

4G telecommunications network

Usual ways to communicate on an offshore rig currently are by means of satellite, microwave or cable connections. These technologies are very expensive and provide limited capabilities. The more cost effective and flexible solution is to use a 4G network, that can be established at all fields. Being facilitated, that would give opportunity to serve onshore with real-time or near real-time data. One of the installations of 4G network in the Norwegian Sea started from the Draugen platform, which is operated by Shell. In a few years, all platforms, even for other OOs, will be equipped with 4G network. That will decrease cost and will have much higher capacity. The 4G network will provide better connectivity for offshore operators, stable reception during the movement stage of the rigs, better communication between different companies by using a single mobile operator, use of antennas instead of wires for Remote Operated Vehicles (ROV), better internet access for workers. (Leach, 2015) This phase has just begun and requires several years for implementation. Without such network, it is difficult to provide a revolution technology (like Cloud technologies) in present. Hopefully in future the 4G will open an opportunity for rig remote control, Virtual Reality (VR) and other internet sensitive techniques.

Cloud

As it has been outlined above, access to the data is vital for any Visualisation Technology. Cloud, in a common sense, may give access to the visualisation data in fault tolerant and highly available manner. It also may make it possible to collaborate effectively for geographically distributed teams or, for instance, offshore and onshore teams. There are plenty other advantages, that will be described later in this thesis. However, there is a one thing worse mentioning, that Cloud adoption is struggling within Oil and Gas industry due data security concerns of major capitals.

2.4 Visualisation innovations

Further in the Thesis are often mentioned such concepts as VR, AR and MR. For a correct understanding of the advantages and differences within these concepts, definitions and descriptions are given below.

Virtual reality (VR) is a software product that replaces reality with virtual reality, filling your vision. A presence effect created by means of using sensors and 3-D audio. The level of immersion is the distinguishing feature from any other technology. The user could move around the virtual world, as it is real. Devices that support this technology are Facebook’s Oculus Rift, Sony’s Project Morpheus, the Samsung Gear VR, etc.

Augmented reality (AR) complements the real world with digital information on top of it. For example, text notifications or simulated screen. This technology has more usability than virtual reality. The user can use his hands while at the same time reading out digital information.

Devices that represent are Google Glass, the Daqri Smart Helmet or Epson’s Moverio brand of smart glasses.

Mixed reality (MR) tries to merge the best parts from VR and AR. The main advantage here is flexibility. Mixed reality lets user to see real world, like in AR, and combined it with virtual objects, like in VR. Then it anchors those virtual objects to a point in real space, making it possible to consider them as "real". (Johnson, 2016) The main device for this technology is Microsoft HoloLens.

Sensor Control

For the successful future of VR and MR, they should be based on advanced sensor network. The challenge is to meet all laws and regulations required for control in Oil in Gas industry for production, usually in non-friendly environments. New generation of sensors allow to reduce cost, facilitate their installation, use the wireless network, early and more accurately monitor the system. (Nina, 2015) The main challenge for VR and MR is to make the system feel. For this purpose, the innovation in sensor network is needed. Now, the existing prototypes are devices in game consoles, the development of “data-glove”. (Wikipedia, 2017a)

3 Review of current situation

This part has an aim to demonstrate the common directions in digital applications in Oil and Gas industry. Examples below show some of the applications and facilities. Nonetheless, it is enough to understanding the tendency in automatization in industry. Mainly the modern digitizing and IT development created new possibilities. But some industries formulate challenges - the base for creation of new software applications. The main challenges from Oil and Gas industry can be described as:

1. More complex operations;
2. Zero tolerance for health, safety, and environmental incidents;
3. The talent and experience gap; (Stefano Martinotti, 2014)

The role of visualisation here is to represent information in a friendly way. That is vital in areas with a big amount of complicated data. For instance, the VISCO company allows by combining 3D graphics, film and programming to communicate better, learn faster and make more efficient decisions. (VISCO, 2017c) That gives opportunity to interact within the whole assets community with better cooperation between personal. The company has strict requirements for their visualisation product. The visualisation must:

- **Utilize existing design data.** It is not about development of new data, it is about using and representing high quality visual model out of existing data.
- **Provide user-friendly experience.** To facilitate intuitive usage of a product. This aspect consists of these factors: users should be able to see a bigger picture, camera movements in 3D environment must operate without lagging and flickering, the visualisation for a regular user must be simple and understandable, with possibility to drive down to the level of a component, for intuitive perception it is important to use realistic content (textures, movement, reflections), for multi-discipline needs the visual tool must be rich enough with features, the solution must be easy to use.
- **Be able to visualize simulations.** It is much easier to understand the 3D model than a static schema.
- **Be connected to enterprise data.** It must be a single-entry point for all enterprise data.
- **Be available everywhere.** For ease of handling, it is important to have ability to use the visualisation model on different devices: PC, mobile, tablets, etc. (Øystein Stray, 2015)

The VISCO provides a special 3D platform for life cycle asset operation (VCOG). (VISCO, 2017b) This platform allows to transform existing data in entire Oil field to the realistic virtual model with possibility to update data at any moment. VCOG also gives possibility to three-dimensional awareness, situation summary and possibility to contribute in 3D virtual operations. (Øystein Stray, 2015)

The following examples will show how the Visualisation Technology is used in several applications. For better perception, examples are divided per functional feature.

3.1 Drilling and completion

Drilling a well is the most reliable way to make sure if a prospect contains oil and/or gas or none. Drilling project includes a wide range of operations. That is a team job including specialists from different disciplines such as geology, engineering, support, management and so on. Most drilling rigs operate 24/7. Drilling conditions may vary considerably from place to place. Also, such elements as the depth of drilling, the composition of the rocks, the surrounding conditions, etc. can vary. (Petroleum, 2017)

Drilling has become much more complex due to:

1. The increase in number of rigs;
2. The increase in complexity of the location of new reservoirs;
3. The emergence of new standards;

The advanced Visualisation Technology and highly-available remote data gathering infrastructure gives a big opportunity for this sector. The main challenge now is to drill more wells safely in lesser time and lesser cost.

Industry studies (Purdy, 2011) published that in 2004 the losses in exploration and development drilling operations are nearly \$8 billion each year. The main reasons are kicks, hydraulic fractures, and wellbore instability due to shear failure. Later internal research by a major oil company revealed that 44% of non-productive time (NPT) is related to incorrect management of annular pressures, which are caused by geopressure and wellbore instability related problems during drilling operations. With the assistance of drilling visualisation software, workers can decrease wellbore instability and reduce NPT. For example, the use of real-time monitoring and updates can give a 20% reduction of NPT (or \$1.6 billion).

Visualisation of real-time data combined with existing model data helps to connect different groups of staff and make the base for more effective and accurate decisions.(Purdy, 2011)

This idea was embodied in the Real Time Drilling Decision Centre (RTDDC). This concept improves the decision-making process and reduce the response time for any problems in advance. The RTDDC consist of two collaboration centres equipped with high-tech Visualisation Technology, as Figure 1 represents, united with a remote data gathering infrastructure.

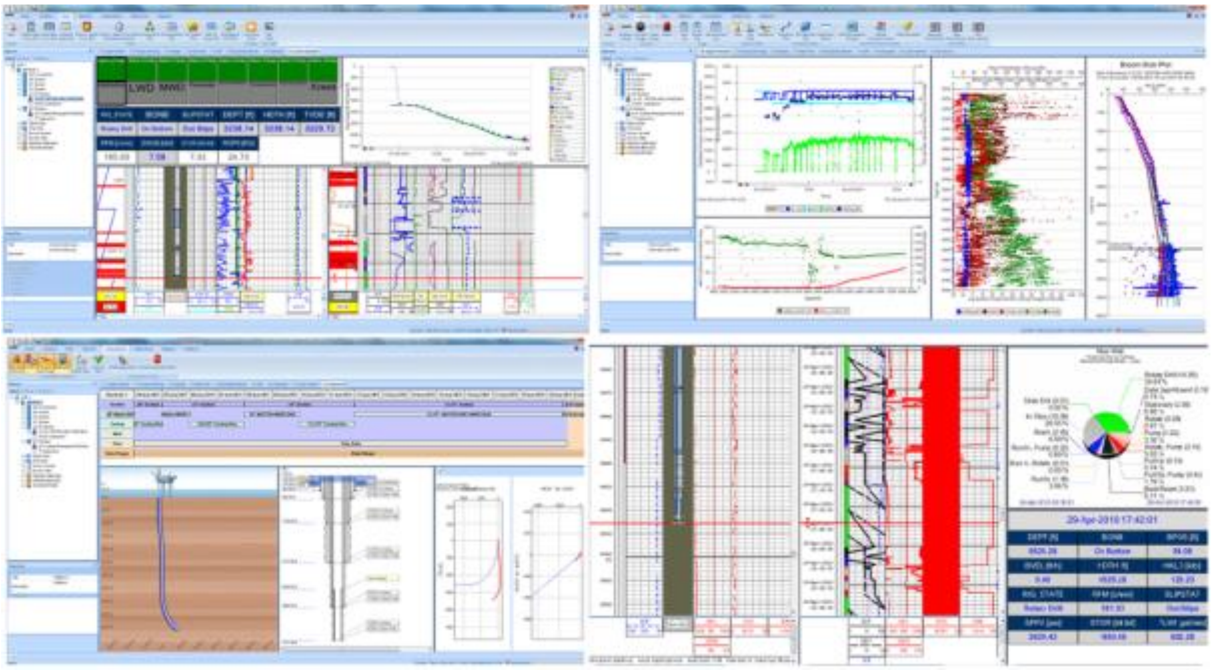

Figure 1. Drilling monitoring (Noha Najem, 2015)

The main pillars that this project implement:

1. Series of actions directed to ensure seamless real-time data flow from the rig to the office.
2. A set of optimization workflows that will help in reducing NPT, finding invisible lost time and optimizing current drilling practices.
3. A supporting collaboration environment to aid improve the decision-making process.
4. Special designed a change management process that help to adapt the culture of the real-time and implement optimization in everyday activities.

This concept allows to reduce the NPT and consequently the extra costs by changing from “reactive” to “predictive” mode. Now, with the plan data and the real-time data decisions can be made in real time. (Noha Najem, 2015)

The Halliburton company uses DecisionSpace® Well Planning software. This software helps to:

1. Reduce the well planning cycle time due to visualisation and automation. Field development planning can be reduced to days.
2. Improve decisions about design and planning. Visualisation of well planning leads to more efficient design. Algorithms optimize some physical parameters. There is a tool for comparison multiple planning scenarios.
3. Preliminary planning reduces NPT and unnecessary environmental impact.

“Decreasing the well planning cycle by 50 to 80 percent means you can spend more time looking at more drilling details and optimizing potential production.” (Halliburton, 2015)

GE and Noble Corporation plc have announced to digitize the offshore drilling rig on four Noble rigs during the next 5 years. This process involves the visualisation of a large amount of data. The companies plan to cut drilling costs by 20% and increase the efficiency of drilling by using this innovation. (Smith, 2017). GE plans to create this product based on Predix software platform. It gives opportunity to aggregate multiple data from different sources, and its proper processing helps to reduce cost and risk and to increase productivity. (GE, 2017) This innovation will allow to move from planned to predictable maintenance. It avoids redundant maintenance in addition to mitigates the risk of maintenance-induced problems, reducing accidental stoppage.

The Fjordnet Limited developed a visualisation product for Oil and Gas drilling process. This program allows "to see the real picture" as deep as at 4,500 to 5,000 feet below the surface. By using a gaming engine and experience in animation the company created a new way of drilling visualisation, as shown in Figure 2. This development allows to work more efficiently and more safely. (Fjordnet 2017) The usage of game engine made this application highly user-friendly and intuitive.

Figure 2. Visualizing Oil and Gas drilling by Fjordnet Limited (F. Limited, 2017)

All these innovations help to make decisions more promptly. This allows to drill safer, faster and place the wells optimally.

3.2 Field development

A hydrocarbon field lifecycle can be divided into five main sections:

1. Discovery;
2. Evaluation;
3. Development;
4. Production;
5. Abandonment;

The field development includes the production facilities design and implementation. A field development plan represents information like:

- the number of wells to be drilled,
- the recovery techniques to extract the fluids,
- the type and cost of installations,
- the separation systems for gas and fluids,
- the method to protect the environment. (IFP, 2014)

It is quite difficult to mature field development plans. However, Schlumberger company introduced the RapidPlan system. It is a new industry product that includes visualisation. RapidPlan helps to create an optimal well placement strategy. This program aggregate information from different sources and processes it. That helps to avoid errors, develop the proper plan from the beginning, rapidly make changes and view the final result. (Schlumberger, 2011) Figure 3 shows the example of visualisation in finding new deviated wells.

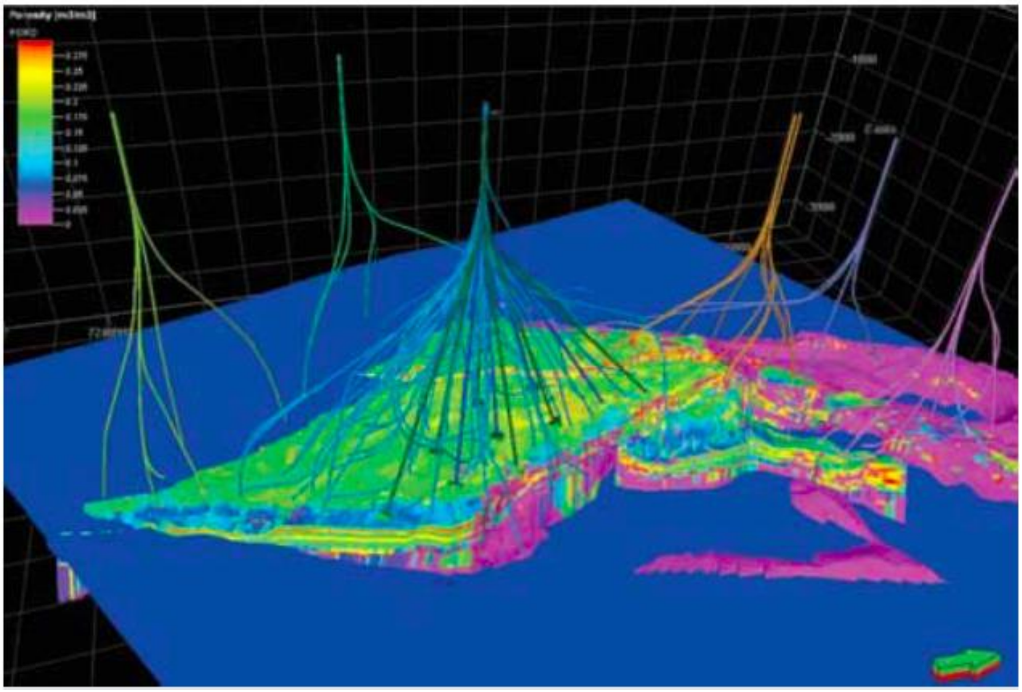

Figure 3. Brownfield FDP example, finding new deviated wells by using both new and existing platforms (Schlumberger, 2011)

The Dynamic Graphics company in turn released the CoViz ® 4D software for reservoir management of hydrocarbon assets. This program allows to trace changing response of a reservoir over time. That information is very important for optimizing production and development decisions. Also, CoViz 4D permits users to visualize the result of development decisions. Figure 4 demonstrates an example of the visualisation when using the program. A large amount of data associated with the hydrocarbon is temporary. Therefore, understanding the changes in the reservoir is very important and play the critical role in asset management. Possible inputs include 4D seismic, reservoir modelling, fluid extraction, well events, production tests and other time-critical data. Data processing is instantaneous. Well planning in the context is available. Visualisation creates a collaborative environment for exploration planning, exploitation evaluation, and reservoir surveillance. All this contributes to faster and more accurate decision-making. (Dynamic Graphics, 2015)

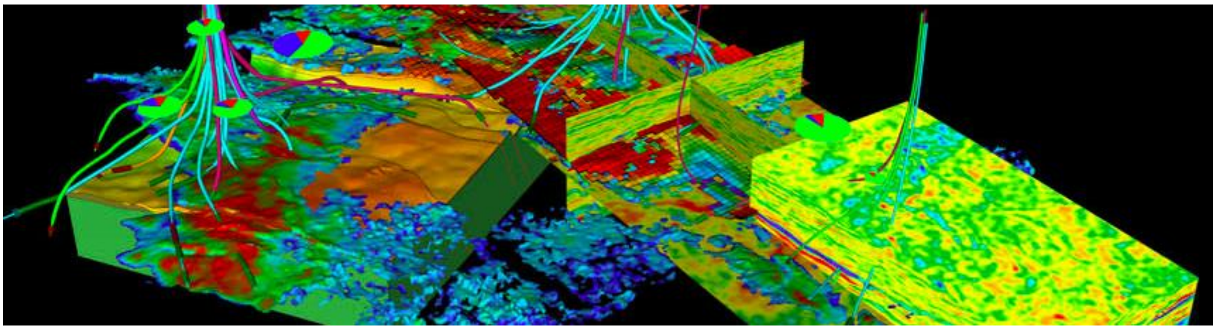

Figure 4. Example of CoViz 4D display view. Integration of multi-disciplinary data. (Dynamic Graphics, 2015)

It is also possible to use 4D model. It is a three-dimensional image considering time. This model takes into account not only geometry and static physical properties, but also dynamic properties. Thus, it is now possible to visualize reservoir with a 20-year life of production, where 10-years are historical and 10-years are simulated. Such a model is the tool to support development planning, which captures different disciplines of the various aspects of operations. (Alberto, 2016)

3.3 Subsea

Subsea operations in Oil and Gas industry implies several activities between the ocean and the sea bottom. Important are: Remotely Operated (Underwater) Vehicle (RO(U)V) operations, subsea tiebacks, seabed boosting & processing, subsea equipment installation, riser design and installation, etc. Visualisation here is used in intelligent asset management, in planning and installation of equipment, for control and monitoring.

An integral part of subsea in Oil and Gas industry is a ROV. The first tethered ROV was developed by Dimitri Rebikoff in 1953. Since that time, this device has undergone significant changes. At first, the ROV started to develop thanks to The United States Navy. Thereby, since 1960s that was possible to perform deep-sea rescue operation and recover objects from the ocean floor. The next step was ROV developed in US for support of offshore oil operations. Now, their tasks range from simple inspection of subsea structures, pipeline and platforms to connecting pipelines and placing underwater manifolds. The ROVs are used widely in the early construction of a sub-sea development and the following repair and maintenance. (Society, 2017) These devices are indispensable in deep water. ROVs are widely used for visual inspection, as it is believed that a diver is more flexible and can perform actions in a limited space. Currently it is a challenge to connect two flanges or to get to a valve by ROV. But divers have a limited depth of immersion. In Norway, it is 180 metres. Also, diving is risky for human life. Time spent in water by a person is limited also. All these contractions and opportunities of ROV lead to the further development. (John, 2014) The following examples demonstrate that the use of visualisation and modern technical devices increases the usability and effectivity of ROV.

The aims for visualisation in subsea is to produce more effective operations and to reduce risk of error. The company EIVA released a product that shows real-time picture of ROVs or other moving objects. Figure 5 shows the operator's view. That facilitates positioning and increases the effectiveness. Also, this product leverage opportunity to do a real visual subsea inspection and provide capability to calculate catenary curves for anchor chains and cables etc. (EIVA, 2014)

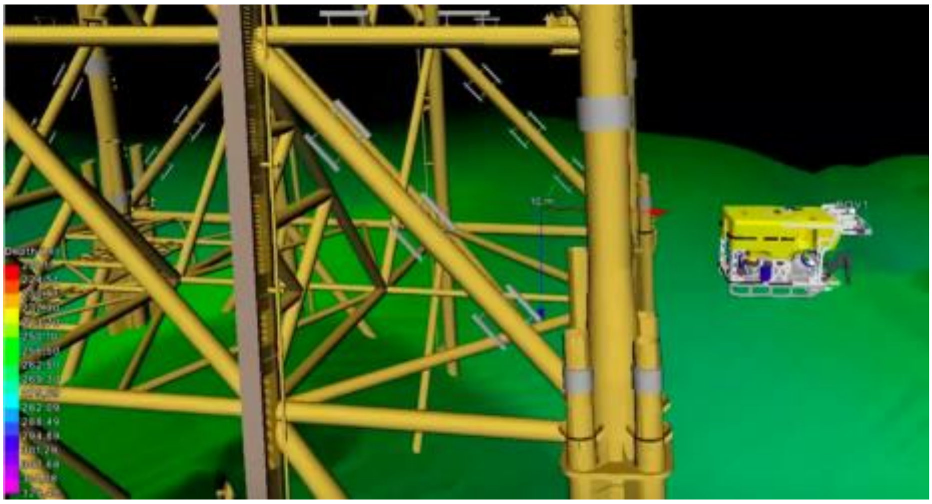

Figure 5. Real-time 3D video ROV (EIVA, 2014)

Preliminary training of operators is required since the control of the ROV is rather difficult procedure. Visualisation in this case do the training process interactive and realistic. QSTAR company introduced a simulator model for pilot preparation. This software allows to train in different conditions of environment, simulate the dangerous situations and teach the newest functions. (SLU, 2014) The figure below illustrates the training pilot terminal.

Figure 6. Pilot Training System (SLU, 2014)

Visualisation in subsea is using not only for ROV. VCOG by Visco is capable to represent 3D model of subsea environment. This product helps to combine all data in 3D model. The model allows to easily locate position of any tag (figure 7), immediately access to information about it, faster check the accessibility, share the field with all stakeholders, see all design changes immediately after making changes. (VISCO, 2017a) Obviously, in conditions of increasing data and the complexity of the environment, the 3D model greatly helps to facilitate perception. Due to the interaction with 3D data, the probability of detecting an error at an early stage is high. Also, efficiency increases due to quick access to the necessary tags.

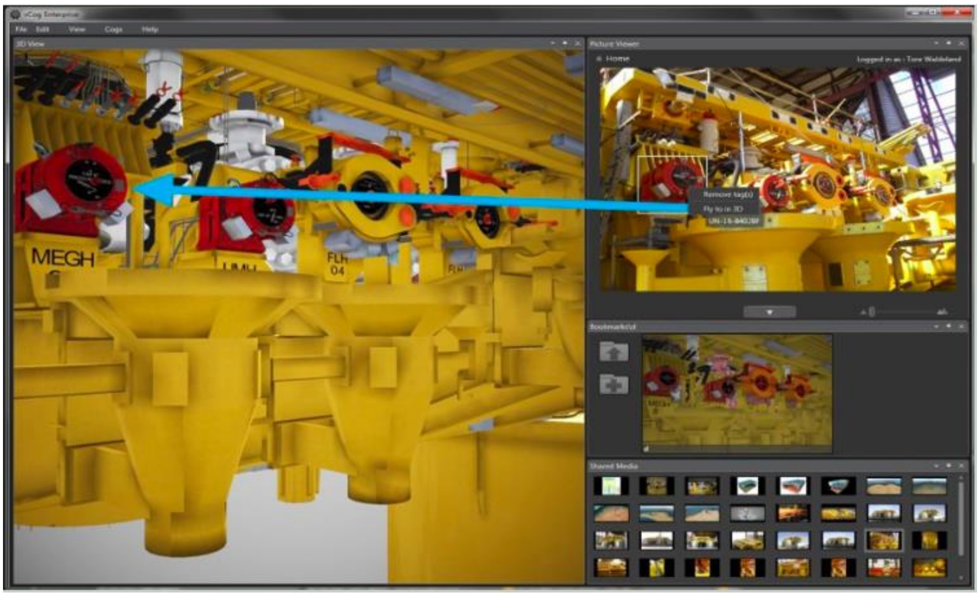

Figure 7. Isolation the position of tag (VISCO, 2017a)

Visualisation in subsea plays a very important role. One of the central advantage is that the risk of losing life is significantly reduced. Also, the gathering of big amount of data gives opportunity of faster decision making. The main benefit is that it is representing control, and monitoring in this area has become more effective and functional.

3.4 Geosciences

Seismic surveying is one of the most important data for Oil and Gas industry. This survey represents location and size of Oil and Gas reservoirs. Sound waves, processed by hydrophones and geophones, are creating a picture of rock types and possible gases or fluids in rock formations. This information has been created by geophysicists interpretation. The final result is the location of possible oil or gas deposits with detailed understanding of geology to depths of more than 10km. (Appea, 2017)

"Petrel, a software platform, developed by Schlumberger, is widely used in the exploration and production sector of the Oil and Gas industry. It allows to interpret seismic data, perform well correlation, build reservoir models, visualize reservoir simulation results, calculate volumes, produce maps and design development strategies to maximize reservoir exploitation. Risk and uncertainty can be assessed throughout the life of the reservoir." (Wikipedia, 2016) This software uses shared earth approach that allows to standardize workflows from exploration to production, enhances multidisciplinary workflows. Also, Petrel provides deep science inception from pre-stack processing to advanced reservoir modelling and then assisted history matching. This product significantly increases effectiveness and reduces risks. (L. Schlumberger, 2017) Figure below shows the one of the screenshots from Spectral Decomposition with Petrel.

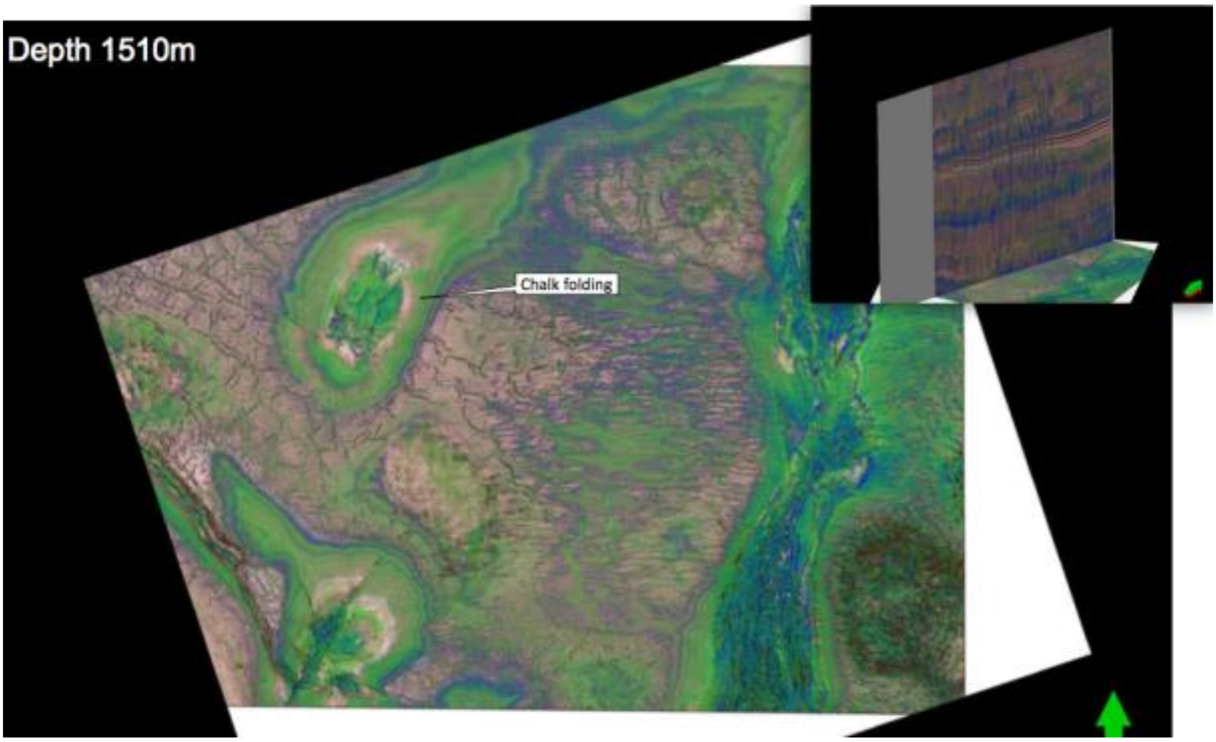

Figure 8. Example of using the Petrel software where the normal seismic as backdrop for the vertical section and coherence as backdrop for the horizontal slice. (Veenhof, 2016)

3.5 Pipelines and transportation

Pipeline is an effective way of transportation in Oil and Gas industry. The length of the Norwegian gas pipeline network is about 8300 km. The transport capacity is about 120 billion cm^3 dry gas per year. The construction of the pipeline network in Norway began in the 1970s. Now this is a developed and present-day system. (Directorate, 2017) Figure 9 demonstrates the pipelines network on the Norwegian Continental Shelf.

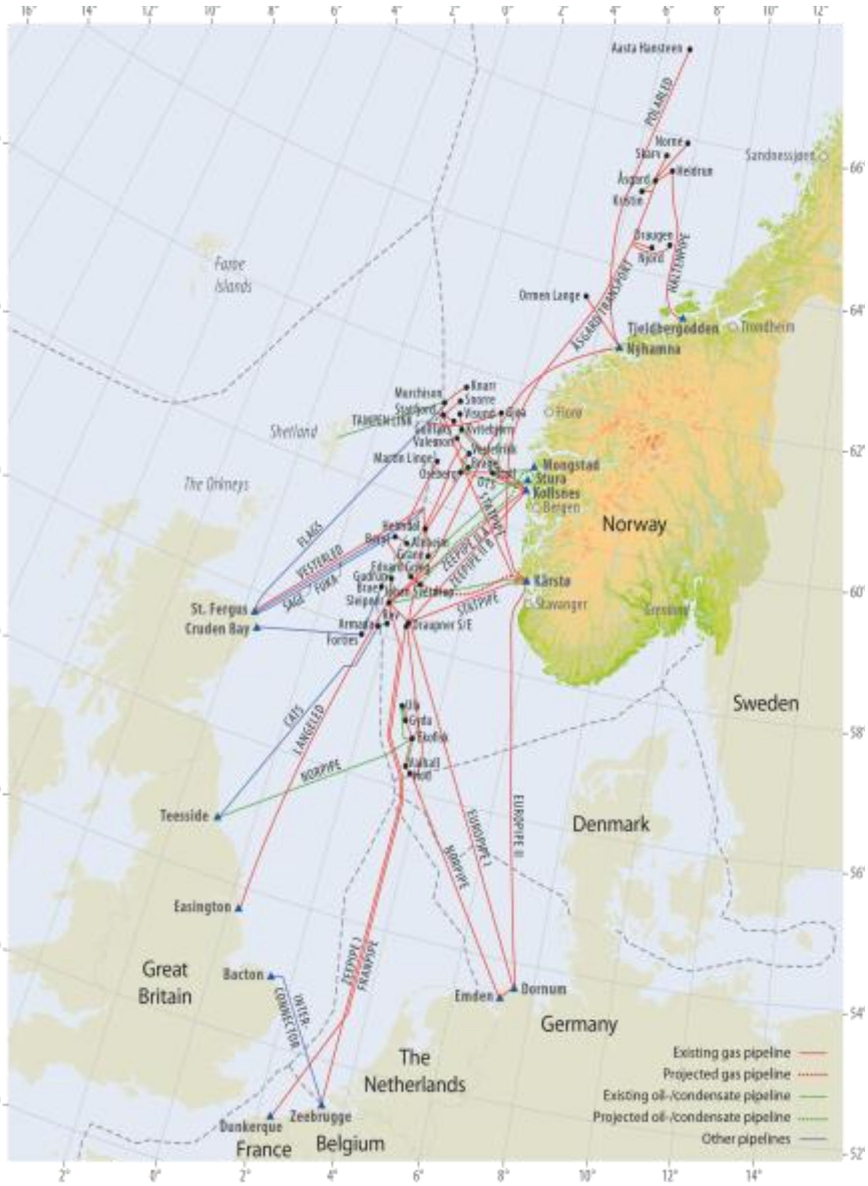

Figure 9. Pipelines on the Norwegian Continental Shelf (Directorate, 2017)

To maintain existing network of pipelines and to create new routes, advanced design and installation technologies are needed. One of such advanced technologies is SIMLA. “The SIMLA software is a special purpose computer tool for engineering analysis of offshore pipelines during design, installation and operation.” (Giertsen, 2010) This product allows 3D visualisation of the pipeline on the seabed. During the lay operation (Figure 10), the SIMLA helps to see and analyse the real situation. That is vital in a very deep water and due to irregular seabed. Also, this software provides additional information such as stresses in the pipe, lay tension, lateral stability etc. Visualisation here allows to monitor the seabed, control the laying of the pipeline, the measure position of the vessel, to control the necessary parameters in real time.

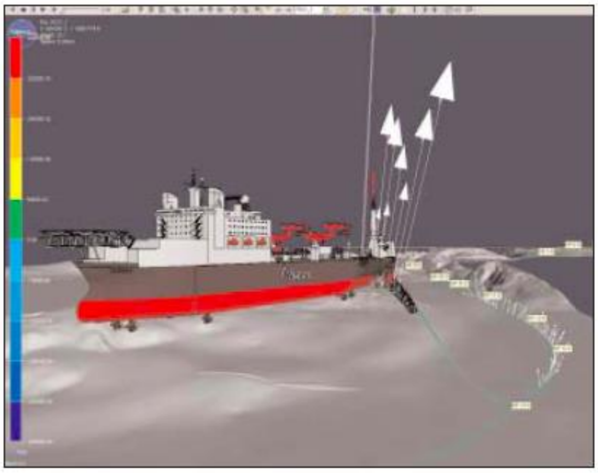

Figure 10. Overview of a pipe-lay operation (Giertsen, 2010)

Another example is Rockwell Automation SCADA host. It helps to monitor and manage pipeline infrastructure. This product involves the latest technologies and developing architectures including Cloud Storage and Process Virtualisation. The company provides the application of visualisation in several segments: pump stations, compressor stations, pipeline safety systems etc. The company emphasizes that these measures improve security conditions, keep accurate inventory, dispatch to the right locations. (Rockwell Automation, 2017)

The pipeline network requires periodic inspections and condition monitoring. With increased service life, the cost of maintenance increases. For pipelines, it is important to provide such a visual inspection for evaluating condition of external coatings and assessing seabed conditions. For a complete assessment of the pipeline condition, acoustic and electromagnetic data are provided. Processing a large amount of information can lead to erroneous solutions: unnecessary repair and maintenance. (Marr, 2010) Visualisation helps to plan inspections in the most effective way. Visual3D-Inspector (Forum, 2017) helps to study the subject of inspection in advance and optimize the inspection process. With the help of the ROVs and Visualisation, it is now possible to study the object of control in advance, to explore area in detail, to minimize downtime and lost production during repairs, to draw up an optimal maintenance plan. (VisualSoft, 2017)

In connection with growing needs for energy, the length of the pipeline network is growing every year. It is important to ensure 24/7 operation. It is worth noting, that the oil pipeline laying in most cases occurs in harsh environmental conditions. And visualisation here helps to ensure uninterrupted operations and facilitate the safe and proper laying and maintenance of the oil pipeline.

3.5 Production

A subsea production system is used to nonstop transportation oil or gas to a floating platform or an onshore facility. In connection with the huge volume of production in the Oil and Gas industry, even minor improvements will bring to great profit. (Stefano Martinotti, 2014) Also production is related with big risks. An error in a subsea production plant could lead to the loss of lives and harm to the environment. Thereby, it is extremely important to make control and improvement in this area. The deeper the water, the harder the production. It requires special tools for this sake: equipment, standards, qualified staff. Many problems are solved by virtual testing in advance. Simulation-based development methodology helps not only create the better plant, but also provide an infra for the real-time virtual test of deep sea production, drilling, etc. (Jong Hun Woo, 2014)

In subsea production, it is important to simulate multiphase flow in pipes. Several companies have developed data-driven models for this purpose. Using such models does not require special skills or insight into multiphase flow modelling. These products allow metering the real-time flow, monitor condition and performance, optimize the flow assurance of production. Also, product combines real-time data with simulation to evaluate the current state and to optimize production. (Grimstad, 2015) Figure below represent the screenshot of LedaFlow software developed by Kongsberg Gruppen. This product gives a basic understanding of complex relationships in multiphase flows. (Harald, 2002)

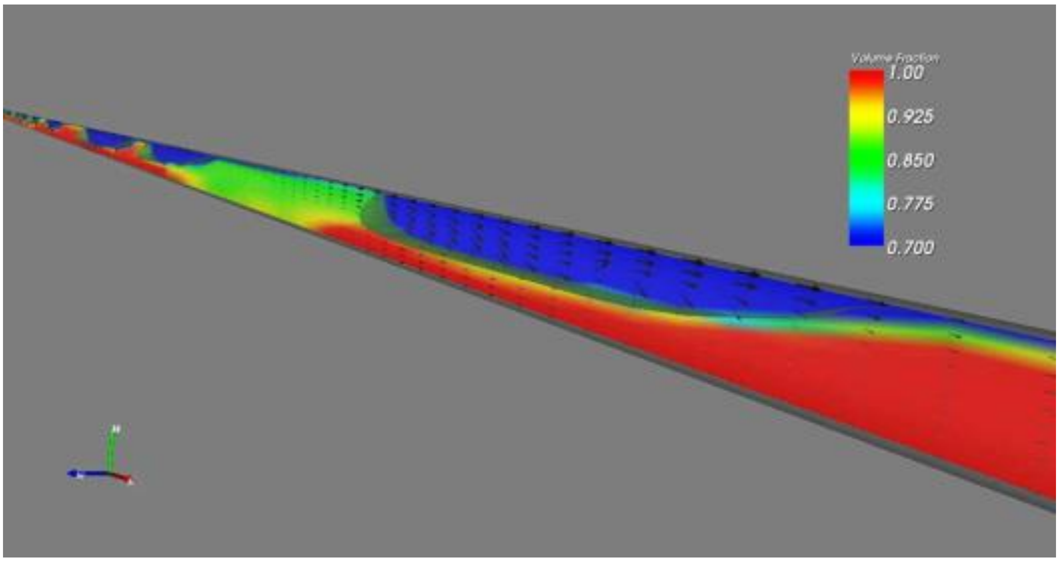

Figure 11. Screenshot of LedaFlow software (Harald, 2002)

For better understanding the whole picture the next part represents the summary review of mentioned applications.

3.7 Summary

The table below is showing the resume of described applications with the identification of the main advantages and features.

Table 1. Summary review

Operation	Visualization tool	Benefits	Page #
Drilling and Completion	Real Time Drilling Decision Centre (RTDDC)	a. Seamless real-time data flow from rig to office; b. Optimization workflow; c. Improved collaboration; d. Change management process for real-time optimization; These features help to improve drilling decision-making process, reduce the response time for decisions and change maintenance to predictive model.	10
	DecisionSpace Well Planning	a. Visualization and automation of well planning; b. Algorithms optimize physical parameters; c. Preliminary planning;	11

Operation	Visualization tool	Benefits	Page #
		These features lead to reducing the well planning cycle time, improving decision about design and planning, reducing NPT and unnecessary environment impact.	
	Predix Software	a. Aggregate data from different sources; b. Data proper processing; c. System wide and improved optimization; These increase efficiency and performance, and help to push maintenance model to even more predictable.	11
	Fjordnet's Ltd. application for down-hole drilling	a. Game engine visualization; This innovative advantage creates a new degree of perception. That helps to improve decision-making process, increase worker involvement and increase the overall degree of confidence and intuition.	11
Field Development	RapidPlan System	a. Visualisation of well placement; b. Aggregate information from different sources and processes it; These features allow to create optimal well placement strategy, avoid errors, develop proper plan from the beginning, rapidly make changes and view the final result.	12
	CoViz 4D Software	a. Trace changing response of a reservoir over time; b. Visualize the result of development decisions; c. Well planning; That helps to optimize production, develop proper decisions and create a collaboration environment.	13
Subsea	EIVA	a. Visualisation of real-time picture from ROVs or other moving objects; b. Real visual subsea inspection; c. Capability to calculate catenary curves; These features facilitate positioning and increases the effectiveness, avoid errors and improve accuracy.	15

Operation	Visualization tool	Benefits	Page #
	QSTAR	a. Interacting and realistic training process for operators; Training in these circumstances gives opportunity to work out important situations: different conditions of environment, dangerous situations. Also, it is capability for fast and effective source of familiarization with new functions.	15
	VISCO	a. Combine all data in 3D model; b. Easily locate the position of any tag; c. Immediately access to information; d. Fast check the accessibility; e. Share the field with all stakeholders; f. See the design changes immediately; These features help to facilitate perception, have high probability of detection errors in early stage and increase efficiency.	16
Geosciences	Petrel software	a. Interpret seismic data; b. Perform well correlation; c. Build reservoir models; d. Visualize reservoir simulation results; e. Calculate volumes of reservoir; f. Produce maps and design development strategies; These helps to standardize workflows and enhances multidisciplinary workflows; provide deep science from pre-stack processing to advanced reservoir modelling and assisted history matching.	17
Pipelines and Transportation	SILMA software	a. 3D visualization of the pipeline in the seabed; b. Monitoring the seabed in real time; c. Providing additional information for control in real time; These features allow to provide engineering analysis of offshore pipelines during design, installation and operation. This leads to reduction in the probability of errors, increasing reliability and reducing costs.	19

Operation	Visualization tool	Benefits	Page #
	Rockwell Automation SCADA host	a. Latest technology and developing architectures (Cloud Storage and Process Visualisation); These innovations help to monitor and manage pipeline infrastructure, improve security conditions, keep accurate inventory and dispatch to the right location.	20
	Visual3D-Inspector	a. Inspection planning; b. Progress monitoring; c. Video control; d. Control of unwanted event; e. Preview of planed work to optimize ROV subsea operation time; Study the subject of inspection in advance and optimize the inspection process.	20
Production	LedaFlow software	a. Simulate multiphase flow in pipes; b. Combine real-time data with simulation; c. Meter the real-time flow; d. Monitor condition and performance; This application does not require special skills for worker of multiphase flow modelling. Features allows to optimize flow assurance or production.	21

Given examples show that all aforementioned Visualisation Technologies software helps to find right decisions quicker and easier as well as creates value in several areas. Main of them are:

1. Increased effectiveness,
2. Reduced risks,
3. Improved decision-making process.

Until recently, the main task of production was only to increase the oil production volume. Due to the constant depletion of reserves, due to the inaccessibility of oil fields, also in connection with decline in the price of oil, the production itself needs to get smarter.

Also, it is clear that all those applications are trying to improve only some designated areas. For improving all over the platform production, it is vital to merge discipline specific software into a unified system. But this task is a very complex challenge. At the same time, this innovation will provide greater benefits, once achieved. Already now, some work has been done for implementing the Digital Oil Platform or Integrated Operations. The Visualisation Technologies here are the core part, as they are a face of the Oil Field. The Unmanned platform and Digital platform are still being designed, because they are requiring significant changes in existing process.

4 Integrated Operations

In our days, special attention goes to the notion of Integrated Operations (IO). In 2004, Norwegian Oil and Gas Association introduced the Integrated Operations program. This program was created for increasing the value on the Norwegian Continental Shelf. (OLF, 2005) IO objective is to integrate processes, technology and people together in strive for smarter decisions. There are two examples of definitions of Integrated Operations (IO) or Digital oilfield (DOF):

“Digital oilfield (DOF) is the application of advanced software, hardware, and data analysis techniques to increase the productivity and efficiency of Oil and Gas production”. The main goals for digital oilfield are in maximizing oilfield recovery and by eliminating NPT. (Technavio, 2015)

“The Digital oilfield (DOF) and Integrated Operations (IO) can be defined as a solution that integrates technology, information, people, process, and organization, using online data to efficiently and effectively maximize Oil and Gas asset performance and value throughout the production life cycle”. (Schlumberger, 2016)

Also, some other sources call it intelligent fields, smart fields, e-Fields and so on. Its main goal is to create value through:

1. Efficient reservoir exploration,
2. Optimization of processes,
3. Long-term development orientation,
4. Improvement to Health, Safety and Environment (HSE) performance;

Definitions above shows that DOF-IO it is not about technology, it is about integration. Erik Alberchtsen (Albrechtsen & Besnard, 2013) represent the table (Figure 12) that shows how the integration lead to the value creation. The stack model specifies that for value-creation data and information should be interpreted and then used to support decisions. (Albrechtsen & Besnard, 2013) Also, there we can see that all levels are interdependent and it is vital to put them in the model in place.

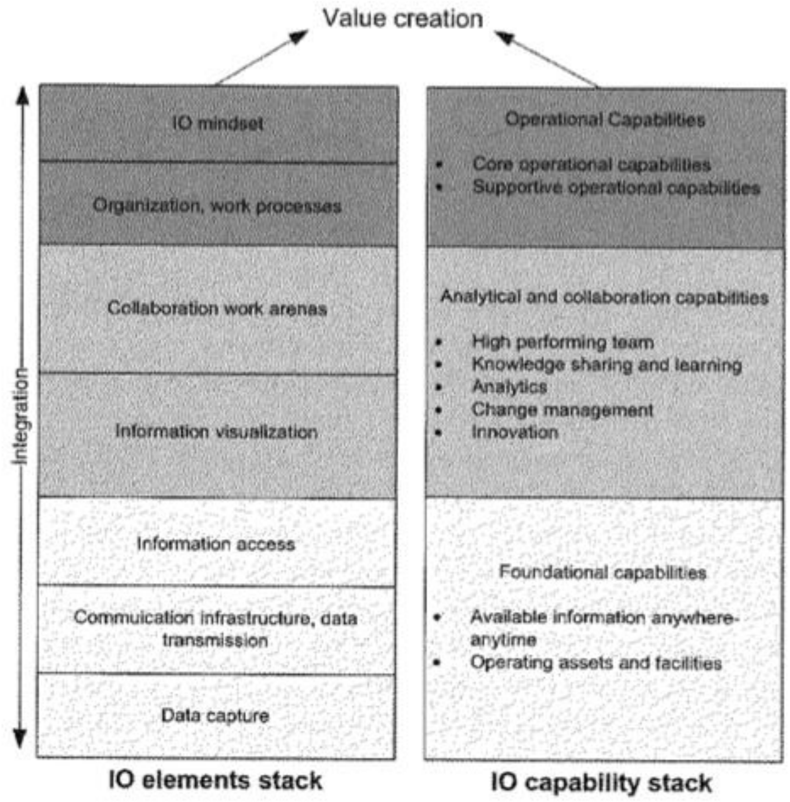

Figure 12. IO elements stack model and the IO capability stack. (Albrechtsen & Besnard, 2013)

Today all the main actors in Oil and Gas industry have some development in this area. Let's consider below the main postulates from Sclumberger perspective. It mentioned, that new technology helps them to transform large amount of data from permanent sensors, historical base and temporary activities to the analytical information. As a result, optimizing Oil and Gas operations. One of the main goals in IO is to connect the offshore field with onshore team. As we see from figure 13, the data from different sensors goes to the software. Further, the processing of data is giving a good base for decision-making process. The connecting link here is the software or interface. (Schlumberger, 2016)

Figure 13. A system of Integrated Components.(Saygi, 2017)

Schlumberger is outlining 8 main steps for data processing in IO. Figure 14 demonstrates those steps. As following diagram suggests, that helps to go from reactive to predictive management, reduce the time to react, predict and thus avoid unwanted events.

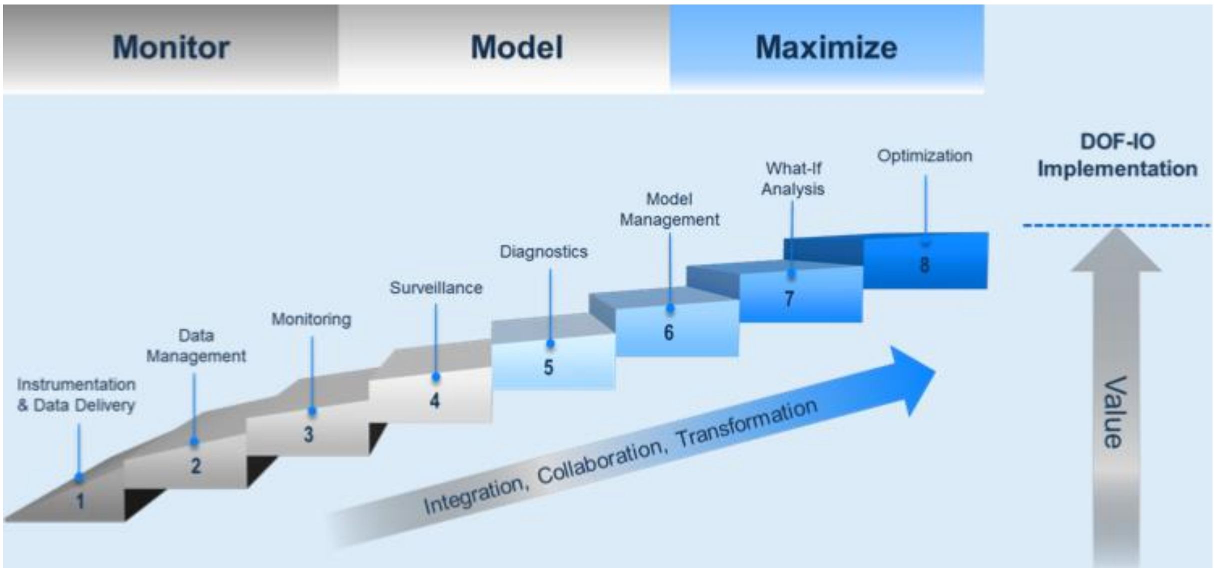

Figure 14. The main steps for data processing. (Saygi, 2017)

These steps will be explained in detail.

1. **Instrumentation and Data Delivery.** Here will be identified the field instrumentation as well as health and availability of communication.

2. **Data Management.** This step checks quality of the data and operational status of data.

3. **Monitoring.** Step responsible for collecting data for further needs.

4. **Surveillance.** It is machine watching data. The step that helps to identify unwanted events.

5. **Diagnostics.** If the problem was evaluated, that step will help with initial troubleshooting.

6. **Model Management.** This step helps to process (tuning, shaping or calibrating) the collected data and to find the proper way for processing.

7. **What-if Analysis.** Scenario evaluation and what-if modeling step. Alternative way to manage risk or improve the system moving to the future.

8. **Optimization.** The main step. Here the best way forward being identified. Schlumberger experts identify this step as: “Decide – Verify – Act”. (Schlumberger, 2016)

The company described in webinar (Schlumberger, 2016) the domain workflow in Oil and Gas industry, fragmented by technical disciplines as shown in Figure 15. DOF-IO makes it possible to consider all this parts for better performance of asset.

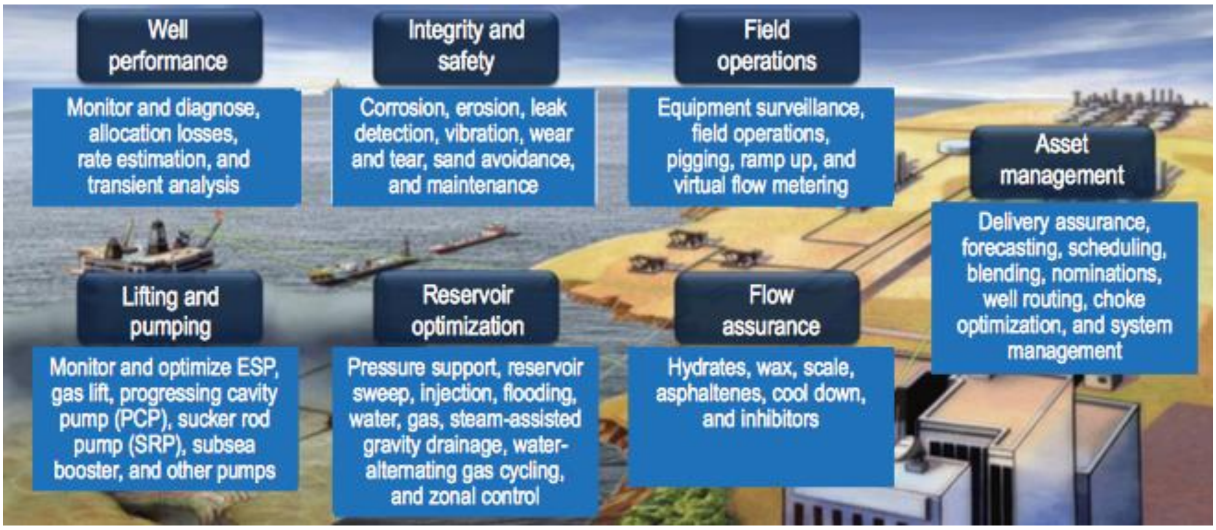

Figure 15. Domain Workflow (Saygi, 2017)

The information from DOF-IO can be easily used at different points within asset time-scale. The Fast-loop processes are means to second by second real-time data evaluation for minimizing operational risks. The Medium-loop workflows, with time scale from weeks up to month, helps to evaluate production and field optimization. And finally, the Long-loop workflow helps to take decisions according to reservoir recovery optimization. The offshore team of skilled people usually more concentrated on short process activities for detecting emerging issues, optimization of field operations and real-time leakage and condition monitoring. The onshore team of experts is usually takes into account long-time scale for fundamental decisions according to reservoir surveillance.

As shown above, the company has developed a detailed and precise plan for the implementation of DOI-IO. The Schlumberger is one of the most significant companies in industry. And the development shown here reflects a common direction among industry participants.

As information above suggests, the DOF-IO is a future implementation of Oil Field. As of now, mature fields already have many wells. That makes it important to optimize production and design cost-effective workovers. It is significant to create algorithms and systems, that will help to leverage existing industry to the digital level in an easier way. DOF-IO gives a huge opportunity in improving all types of processes. This innovation considers real-time data as well as historical data in different aspects.

5 Information processing

Relatively recently, the Oil and Gas industry began to change in connection with the development of technology. In the past, offshore production required all qualified professionals directly on the platform. But already now, many works are transferred onshore, to be carried remotely. As the number of people on the platform is reduced, this improves HSE and reduces costs, reduces the need for underwater diving. But, if necessary, divers have opportunity to use advanced technology for better visibility and efficiency. Transition to digital media significantly reduces the likelihood of errors and improve collaboration. Although the Visualisation Technology began to implement recently, it has achieved significant changes and improvements. And this is only the beginning.

Here will be discovered the main steps for Interface (or Visualisation) creation for DOI-IO. As it was mentioned before, the visualisation here is a face of Oil Field. But it is not enough to represent a 3D model of platform body, for example. The visualisation should meet a number of requirements.

The core here is to collect the right data in a proper way. As figures 16 and 17 shows, different companies use different base for visualisation creation. But the idea is the same: the visualisation should have a full informative basis and be very useful. The successful implementation of this step will lead to the solid base for future decisions. As we see from figures, the main part is asset side and the other is user side, and they are interconnected.

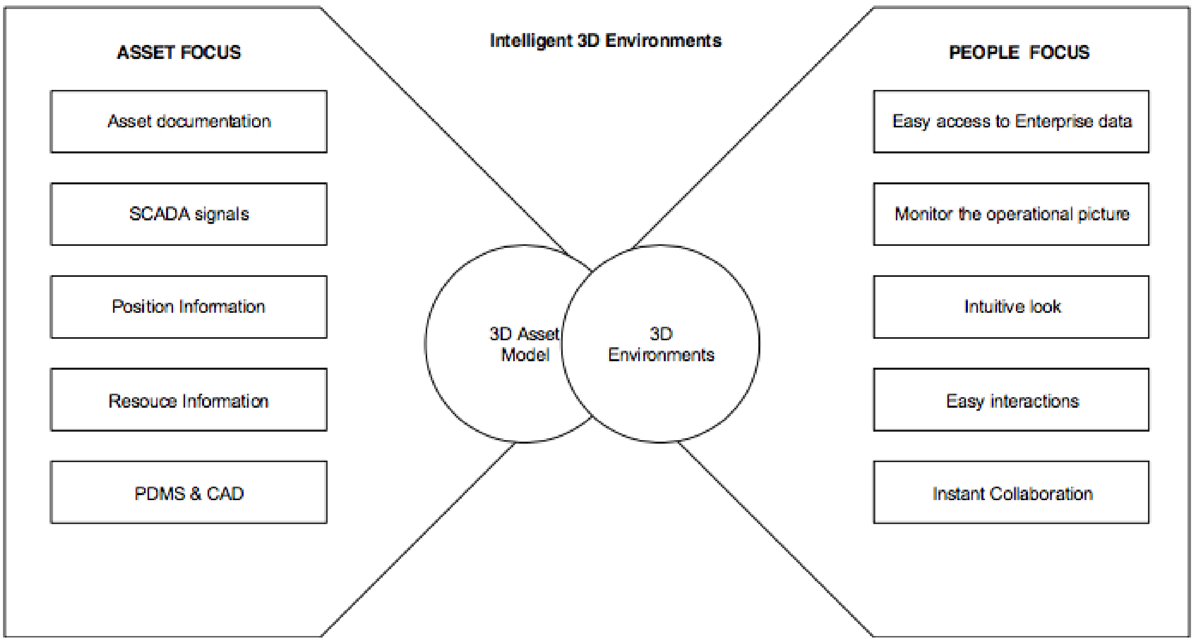

Figure 16. Intelligent 3D environments is based upon technical asset information. (Øystein Stray, 2015)

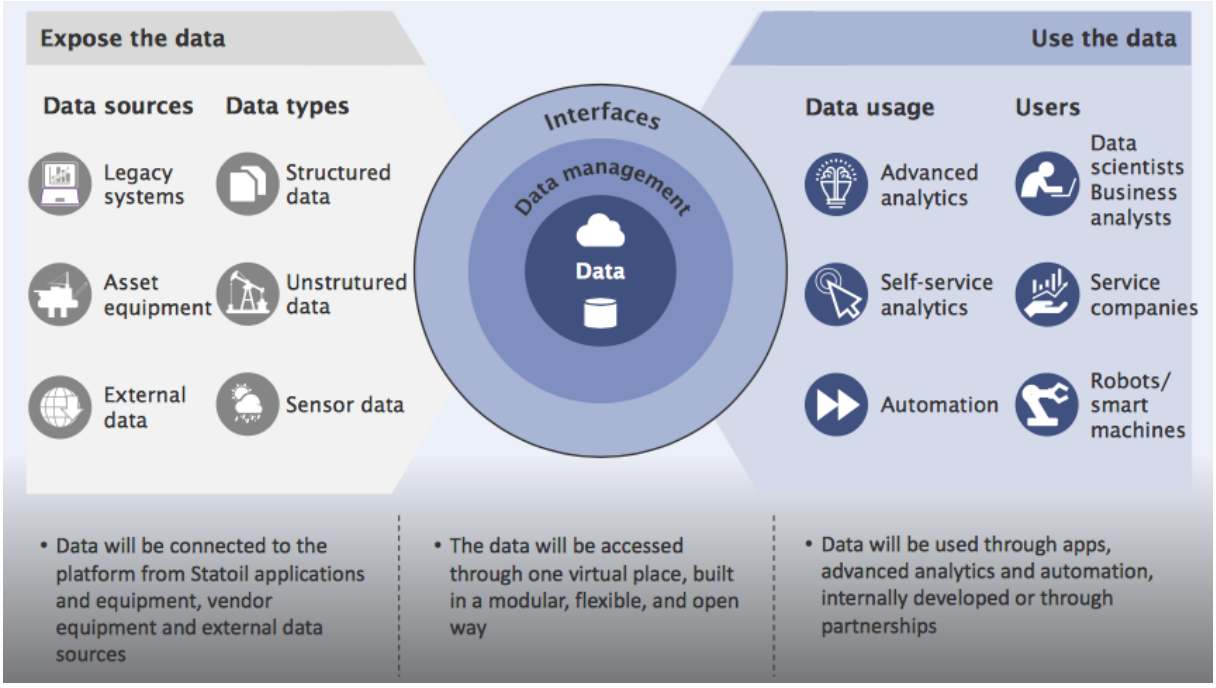

Figure 17. Interface from Statoil is based upon database and user needs (Vermedal, 2017)

5.1 Data

The best information for managing field comes from the field itself. (Mabro, 2006) That can be historical records or real-time information. It is a million tags per hour from sensors (Schlumberger, 2016), different formats, different usage purposes… Data is vital and critical. It is a really powerful tool that, in combination with analysis, can provide insight into the design and operation any rig aspect, and ways to improve it. That is not real to create DOF-IO without such instrument like information. Nowadays tendencies require to capture and proceed more data than ever before.

The first step is to identify and collect all data. The information comes from different sources. That can be sensors, weather services, reports from service companies, seismic documents, emails, market feeds, etc. All data that platform generate must be collected and persisted as well. Also, information should be processed and represented. Why all information should be collected? Analysis of the use of equipment will give an opportunity to create a better plan for maintenance, comparison historic data with real-time production can help to analyze and identify unwanted events in advance or this information can be a material for the investigation of events in future.

Following, some challenges have been indicated:

5.1.1 Formats

The standards that identify how data is defined, formatted, stored and viewed can be implemented for new oil fields. 'Open data exchange standards define data types, naming conventions, formatting rules and various other meta-data for the management and processing of the information within various technologies and software applications,' mentioned the resource manager from PPDM (PPDM, 2012) This can help to share data between different participants and transfer data to the DOI-IO automatically. But as some existing platforms have been running for decades it is a challenge to aggregate data in this case due to quite a few data formats, coming from different data sources. That can be historic data, electric logs, paper copy in a distant office, VHS, DVD, PDF-files, etc. Some information need to be digitalized. Some data need to be reformatted. At the very end: all data should be organized, have a right access and shared by different disciplines and vendors.

5.1.2 Fragmented and unstructured data

For successful exploration, it is vital to analyze all types of data in a proper and timely manner. That is a challenge because majority of possibly useful data taken today is not normally stored, nor is it dispersed to the people who can use it to the maximum. It is because Oil and Gas industry mainly operates with a big amount of fragmented (Figure 18) and unstructured data, e.g. out of context data, and mostly this information comes from important sources, equipment for instance. The aim here it is to find such information, persist it and make sense out of it when required. That allows to see data in a convenient way and thus use its full potential of context.

Shahbaz Ali mentioned that 80% or more of all data estimated are unstructured. He represented Three Pillars of Unstructured Data Management:

1. Storing unstructured data,
2. Controlling risk,
3. Understanding information; (Ali, 2013)

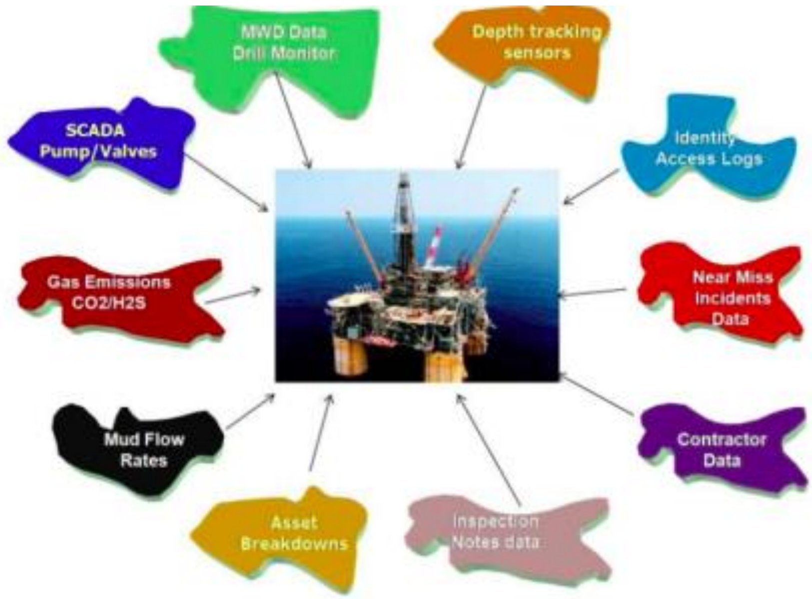

Figure 18. Fragmented Oil and Gas data pools (Jose, 2013)

Also, this understanding of data will give opportunity to use the same object in different groups of workers, in an interdisciplinary manner.

In context of unstructured data in Oil and Gas industry notions of Data Mining and thus Big Data can be introduced. "Application-aware data mining and analytics reporting is possible today, based on data flows from unstructured data stores. Only 3% of data is tagged and less than 0.5% is analyzed. IDC further estimates that by 2020, as much as 23% of data will contain value that modern Big Data techniques and technologies can extract and harness" (Ali, 2013) As numbers suggest here, it is clear that this area still require big efforts. Working with information in this context can give an understanding in underlying trends. As a result, that can help with avoiding unwanted events and discover events that can help to increase profit.

5.1.3 Poor quality data

Decisions based on poor-quality data can lead to disaster in any business area. But mistakes in Oil and Gas industry can lead to unacceptable human loses and significant financial losses. William Cummings declares that "poor-quality data costs the average company a staggering $14.2 million annually" (Wolliam, 2015). Incomplete database, unwell updated documents or information dispersed in different systems – all this are reasons for poor quality data. For improving this, the data must meet four requirements as mentioned in Figure 19.

Figure 19. Quality data requirements. (Emmanuel, 2017)

For accuracy, it will display the relevant degree of representation of reality. To guarantee that certain attributes continuously have assigned values in a data set or to guarantee all appropriate rows in a data set are present, the data need to meet certain degree of completeness. Quality data must be consistent across the board. Timeliness is responsible for the relevance of information. (Emmanuel, 2017)

It is impossible to create a viable interface without good quality data. One of the suggestion is to implement a data quality program. But it is more important to start from organizational culture. This leads to an understanding of the importance of the data by employees.

5.1.4 Mature fields

Mature platforms were installed more than 20 years ago and have “old” software. This software upgraded and improved all over the time. But not to the extent of easy data collection and persistence. Because of the databases used in these software, vendor locked equipment, complexity of the original source code, it is hard and costly to rebuild these programs. “Pen and paper are still remaining the most popular method of day-to-day production reporting” said Greg Archbald in his article (Archbald, 2017). This outdated method of recording data can lead to loss of data and, as a consequence, to error and impossibility to merge with new technology.

To give an example of “old” program, the Supervisory Control and Data Acquisition (SCADA) can be considered. This program was developed in 1950s. It has been improved all over the time. The limitations that can be seen today:

1. Underlying data structures are not set up optimal;
2. Low fidelity of measurement and data storage ranging;

3. Communication issue;

4. Require manual mapping of register value; (Industrial Internet Consortium, 2015)

Improvement in this area can lead mature platform to a new life. But this step requires significant money spending and restructuring in equipment and employee's sectors.

All Oil and Gas companies trying to improve their way to work with data. It is new and smart approach to manage data and to work with digital assets. Today's target is to translate a raw data into information that can be used by right person in the right format and in right context. For example, BP uses intelligent monitoring. The company proprietary Data Lake holds more than 1 petabyte of operational data, they record more than 99.5% of information of any single system. For advanced prediction, BP compare historical data with information from similar yet more modern fields. (BP, 2017)

5.2 Human adoption of Visualisation Technologies

Previously it was mentioned that the data is very important part. But having only information is not enough for Visualisation Technologies. Without people focus all these systems have no sense. The main aim here is to get maximum from the data for users using fast, intuitive and safe instruments. This part describes the main steps for successful human adoption of Visualisation Technologies.

5.2.1 Access to data

Creating unified database with easy and purposeful access gives an opportunity for great improvement. It is vital for DOF-IO. Only visualisation with connection to enterprise data creates value. There are some benefits:

- possibility to see how any change can influence to all system;
- represent all picture for experts;
- utilize data all over the world;
- reduce time for looking for information;
- accelerate workflows;
- increase productivity;

It is important to have access from different devices in different locations. For example, in offshore operations it is useful to utilize data in a distance from main computer. Also, this step is a basis for future improvements. That would really help to create high-level collaboration and situational awareness.

As it was mentioned before, Cloud computing helps to reduce NPT, costs and risks. Stefan Stroh and co-authors mentioned, that spending in total and operational use of company's data center can be reduced by as much as 40 percent. (Stefan Stroh, 2009) This can be reached by eliminating such activities as maintenance and service of servers and hardware provision, cooling, reduction of electricity consumption. "Everyone will have access to everything they need, when they need it. Employees that leave will no longer walk away with all of the company's knowledge and experience." (Council, 2017) That gives opportunity to use unified interface not only inside corporation, but to give access for partners or service organizations. The usage of Cloud reduce cost, increase the communication speed, improve effectivity and increase the data safety, though exposes security risks.

5.2.2 Situation awareness (SA)

"SA is the cognitive skill of knowing what is going on around oneself and using that understanding to predict how the situation may develop in the future" (Prithvi Raj Ramakrishnaraja, 2017)

Monitoring the operational picture is the most important task. Also, a creation of high level of situation awareness design is a big challenge for making 3D environment. The notion "situation awareness" or "situational awareness" started to be used in military. They utilize it for improving performance and decision-making process. In other words, SA can be described as core layer for decisions in condition of rapidly changing environment and with a huge number of influencing factors. With increasing complexity of the systems, the system awareness becomes more difficult and the probability of error also increases.

Specialists from SA Technologies Inc. represented two steps for SA for military: (Endsley, Bolstad, Jones, & Riley, 2003):

First, it is important to identify all key goals, but also all sub-goals. Based on this will be represented the major decisions that must be done. This analysis based on goals, not tasks.

Second, development of a system design that will cover all requirements. That is a most challenging part. Here should be met several requirements. For example, recommended:

1. Presentation of higher level situation awareness;
2. Representation of goal-oriented information;
3. Support the global situation awareness;
4. Deriving critical cues related to the key features;
5. Removing irrelevant information;
6. Multi-models display should be provided in data rich environment;

It is important to evaluate SA oriented design during design phase. That will show effect of the concept. For this purpose, the Situation Awareness Global Assessment Technique is used. The main advantage in real operational environment is that the impact of design decisions can be accurately evaluated as a measure of quality of the integrated system design.

Below some examples from military practices represented. Displays have been developed for usage by different type of military personnel. The program includes possibility to gather different data depending on the present objective. Here we see how integration of big amount of data transformed into accurate and relevant picture of existing situation

Figure 20 shows that military operator can easily see information through different types of filters depending on his/her purpose.

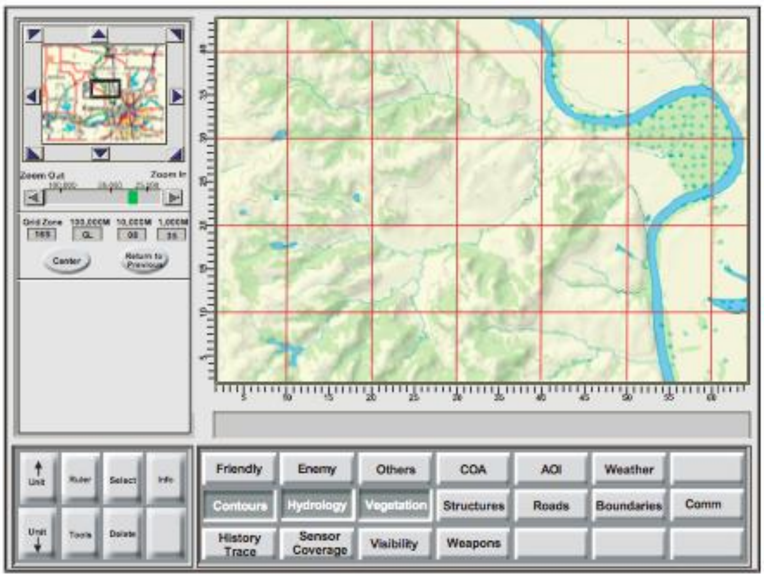

Figure 20. Intelligence analyst map (Endsley et al., 2003)

The next figure demonstrates course of action and history traces showing past unit movements. This data complemented by higher level information. It represents sensor coverage area, weapons coverage area, etc.

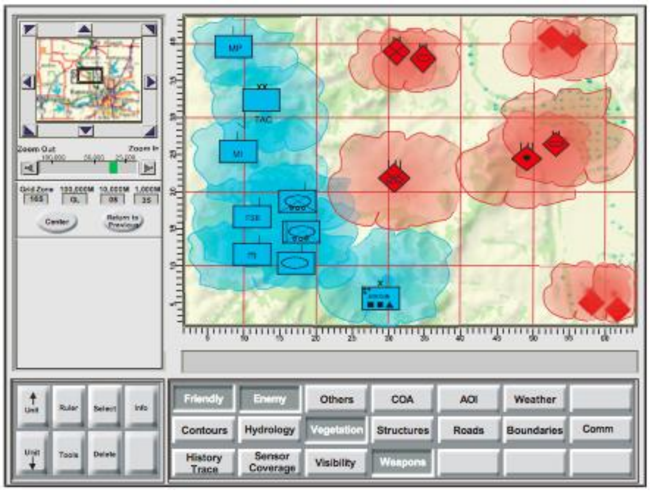

Figure 21. Map showing weapons coverage areas (Endsley et al., 2003)

Certainly, in SA for military it is important to track a status of supplies. The schedule display allows to track shipments, to plan and control the supply schedule, to calculate usage of units, to plan anticipated need of different goods, etc. Also, it is possible to make a link to weather conditions.

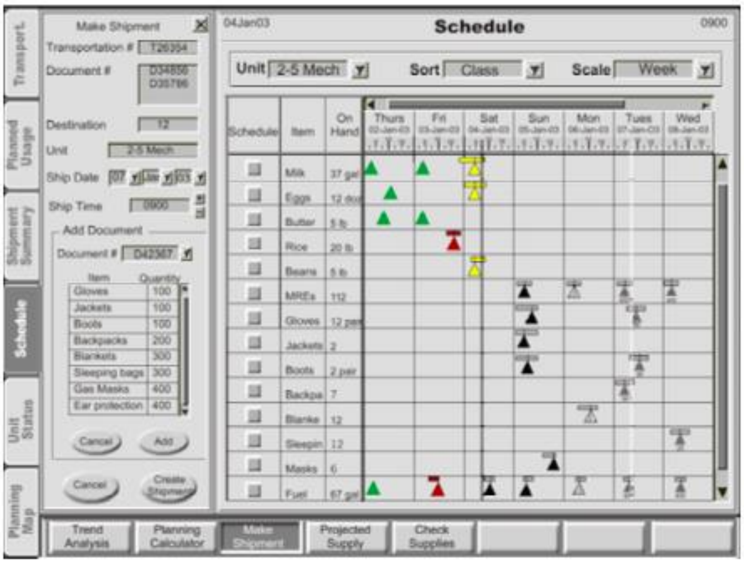

Figure 22. Schedule display (Endsley et al., 2003)

These are not all tools, but represents amount of functions military operator has and their ability for customizations, that are meeting needs of objectives, useful for different level of servicemen. It creates a high level of SA. (Endsley et al., 2003)

It is important to mention, that military and Oil and Gas industry have several common points. Schematically common links can be shown as in figure 23.

Figure 23. Schematically links between Military industry and Oil and Gas (Mark A. Bartram, 2009)

SA can be divided in three levels:

1. Perception. It is important to continuously monitor work environment;
2. Comprehension. The level where the picture of the situation is obtained;
3. Projection. The result of future forecast based on levels combination; (Watch, 2013)

As practice shows, in Oil and Gas industry errors can be spotted at all levels. And mistakes can be a very significant. With proper SA, that would be possible to avoid Deepwater Horizon incident and The Piper Alpha disaster.

SA in alliance with visualisation on Oil and Gas platforms can lead to many improvements. For example:

1. SA link platform directly with suppliers;
2. SA indicate the important emergencies, that should be considered right now;
3. SA lead to predictable maintenance;
4. SA give opportunity for remote monitoring of equipment;

The recent developments in industry, increasing data and complicated equipment leads to a more complex environment in platform. It is more and more difficult for employee to monitor the situation. Consequently, SA starts to be vital. Proper visualisation here is required. It is extremely important to give an opportunity for real-time conversance in a comprehensible way. This step not only improve safety situation, but also improve the platform life.

With the development of technology, it becomes possible to use Augmented Reality (AR) and Mixed Reality (MR) for SA purpose. That can strongly help to understand the current situation and to predict the future. Some implemented developments showed that AR can help diver to navigate and act in underwater environments, people can have a faster understanding of situation and can take a more confident decision. (Prithvi Raj Ramakrishnaraja, 2017) Using glasses with AR can create possibility to be aware about dangerous situation, even if employee is not near the control room or has partial access to required data. AR and MR also support collaboration. These technologies can be used in all phases, from design to well closure.

5.2.3 Collaboration

The aim is to develop a collaborative understanding of problem-solving between teams (offshore, onshore, experts, service providers). Also, it opens a possibility to transfer some tasks from offshore to onshore. That leads to risk reduction and cost saving. For example, reducing the number of helicopter flights. The use of instant collaboration mains to improvements in the coordination and communication of tasks, and lead to quicker response from onshore team or external experts. The technology today helps to create a real-time easy interaction through video technology, customized software and mobile devices. Coordination center can be used by several drilling operations, numbers of skilled works from different divisions (operational geologists, data engineers, directional drilling, etc.).

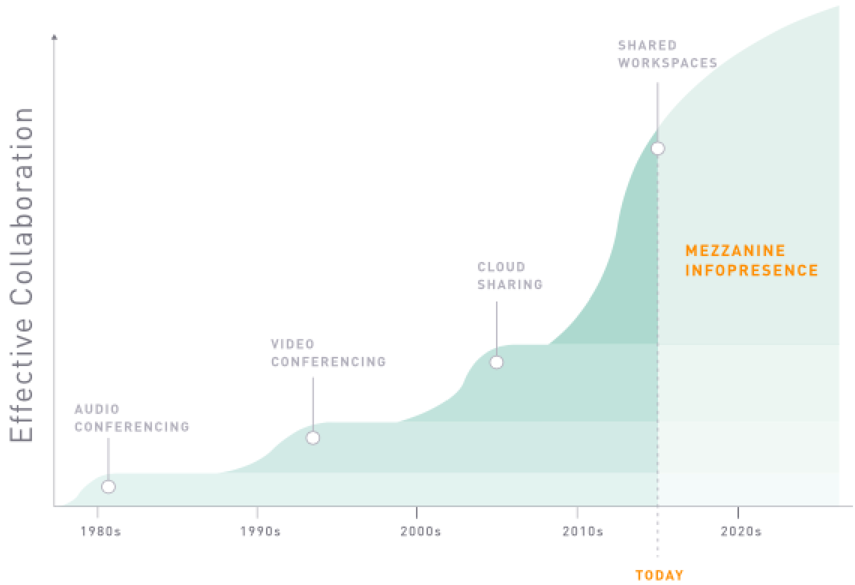

Figure 24. The Evolution of Conference Room Technology (Oblong, 2014)

Future development relates to the latest technologies. Use of AR, VR, MR, “data gloves” can make a huge breakthrough in this area. For example, VR can eliminate the distance factor. It will make it possible to have expert review at any point all over the world. The ability to "touch" the equipment can remove the real presence requirement.

But the main point is to find fast and balanced decision. Collaboration centers highly contribute to that. It is important to provide them secure and fully integrated environment. That is achieved by sharing information, ideas and knowledge without territory factor.

5.2.4 Intuitive look

This step is crucial for the implementation of the entire system. Intuitive look means that worker does not require training for using interface. The target is that worker can use his specific existing skills for managing new technologies and innovation. That gives opportunity to skip a huge amount of trainings, and use only advantages of a worker. In our case the interface should give opportunity to manipulate a huge amount of data in easy way, contextually. The fulfillment of this condition will significantly improve employee’s productivity.

The creation of intuitive look is a complex process. However, there are some suggestions, that can be implemented:

1. Develop the most effective, but not overloaded screen. This screen should represent maximum of needed context;
2. The control panel should be easily accessible and understandable;
3. A well-thought-out navigation system inside the system and between applications;
4. Convenient search. The most frequently used tools should be in the accelerated search, keeping the hierarchy when you dive into the details;
5. Capability to consider the screen in different contexts for different players;
6. The main function should be obvious and correspond to the expected human behavior;
7. The interface should promote learning within: a quick video, a tool tip, an accompanying drawing, etc.;
8. The text content should correspond to the topic;

9. The ability to give the choice for users can cover most queries. For example, the search can be represented by voice command, by text, by pictograms (McGrath, 2011);
10. Give the ability to interconnect and use different equipment: mobile, PC or tablets;
11. Develop levels of security. Levels, where the employees will have the necessary range of data for their work;
12. Make it possible to customize the system;
13. Use previous experience in software for better adaptation;
14. To create a realistic picture, it is needed to use different textures and colors;
15. Prevention of errors. The interface must help to users in adding the information in a proper way or to use dials for preventing mistyping numbers;
16. Use a color code or signal code can be helpful. For example, red color and special noise can show a critical situation;

Also, an important point is refinement. This can be facilitated by execution of numerous tests, feedback from users, adjustments. What is intuitive for one person is not necessarily so for another. The suggestions above are not mandatory. The key factor here to understand "who needs what" (Wagner, 2016) and give the interface that can meet this requirement.

Game engines, AR, MR, 3D environment are helping to reach intuitive look objective.

For example, 3D environment is more like reality then 2D. Because of that, it is easy to understand and monitor in this case. Decision, based on 3D model, is more conscious. User involvement is higher.

AR and VR are connecting with the emotional aspect and can bring human-machine interaction to a new level. It can be possible to give an immediate response from the worker, by reading his emotions and by immersing himself in a realistic computer model.

5.3 Perspectives

The information above shows that creating a proper visualisation is a complex job. The result of this job can lead to significant benefits. The aim of this chapter is to show that visualisation creation process helps to significantly increase quality of all work routines across the oil production and thus increase profit. Changes that happen in Oil and Gas industry is not only associated with technological development. There is a reduction in qualified staff, oil production is not “easy” anymore, economic crises have affect and so on. And visualisation can help here.

Creating a unique and complete database by using Cloud computing and Data Lakes/Big Data can be a first steps to create “knowledge base”. As all data are recorded and understood, the decisions from skilled staff will be recorded too. Using an Artificial neural networks (ANNs) makes it be possible to teach the machine the appropriate behaviour. This will help not to feel so acute shortage of qualified personnel. Also, the excess link can be removed. For example, by setting up automated program, which purchasing equipment directly from supplier. The application itself will carry out purchases, by knowing the name of the product, possible analogues, the number of pieces, etc. This process can be based not only on historical data, but also on the current state of the system, or better both.

Using the removal control, modern sensors and progressive SA can help to develop and produce oil in inaccessible areas.

A huge amount of application, for such technology as AR and MR, can be an incentive for future innovations. Special glasses can be used for helping in maintenance, as system will give some real-time suggestions, tooltips or sequence of maintenance actions. In design phase, it may be possible to test various options for building platform not only as a picture, but with the effect of presence. During operation, AR and MR can help quickly respond to an unusual situation, pave the way and show the path while searching for the necessary equipment. A detailed study of the equipment can be provided: the possibility of rotation the equipment and ability to examine in detail the smallest details, the possibility of considering the all probable cuts, dependent devices, the place in the common system and so on.

VR is the next step. With this technology, the employees training start to be more precise and more effective because environment will look exactly like on a real specific platform. In addition, VR provides an opportunity to engage any expert in the world to address any specific issue remotely. That will help to take faster and better decisions. Soon, VR in tandem with robot technology can significantly reduce number of employees on the platform.

And for sure, all these innovations lead to cost reduction. Since the cost of oil now is declined, this aspect is very important. Reduction in the number of staff, use innovative technologies, use of predictable maintenance, use of remote specialists on demand - all these aspects are leading to cost reduction.

This chapter has shown advantages and disadvantages of information processing. The visualisation creation has a lot of gaps that will require changes at many levels. At the same time, the benefits are very significant. The proper visual product can be a basis not only for newer platforms, but it can also be basis for modernization of mature fields. Also, the development of technology facilitates unmanned platforms development. Most of OO conduct research and development in this area. The Visualisation Technology here is a core factor. Such prospects reflect current trends and courses. Until recently, those prospects would seem fantastic, but with the development of technology it is only a matter of time.

6 Discussion

Growing needs for energy and strict operational demands dictate new requirements for Oil and Gas industry. Evolution in Visualisation Technology together with the latest development allow to meet overwhelming majority of those requirements. Visualisation is highly contributing into simplification of operations.

Visualization Technologies as such is a rapidly developing area, and it is already giving significant advantages. Employees may have the opportunity “to see” previously inaccessible areas of data, work in a cross-discipline context, utilize the power of reach and intuitive graphical interface, which tailored to their needs. As it was mentioned, there are a lot of applications that improve operations and increase Business value. Daily, software companies are trying to bring something new to everyday operations by means of innovation. Another important advantage of using Visualisation Technology is improvement in training, usage and educational processes. Visualisation here contributes into reduction of time factor and improves quality of value provision and rate of user acceptance.

Though despite all the benefits in Visualisation Technologies, there are many shortcomings that need to be in place. A lot of work must be done upfront for modernization in data management, being a key factor for Visualization Technologies to be valuable.

Creating visualisation of Oil field will lead to embodiment of DOI-IO. Having Digital asset in place may open whole new ways in day to day operations, allowing community like access to any asset aspect, simplifying routines and collaboration. Subsequently that may lead to commissioning of unmanned platform as a major unit of offshore operations. This is an ultimate aspiration now in the industry.

In my opinion, Visualisation Technologies require a set of standards. A standardized approach can greatly facilitate implementation of future developments and innovations, as well as data interchange between involved parties. It will also allow to quickly adopt new and historical data and structures. Also, new visualisation tools require further detailed study. For example, research on the usage of VR, AR, MR. While AR and MR does not switch a human of from reality, VR may and thus can lead to loss of sense of reality for humans while task execution.

As literature review revealed, visualisation area in Oil and Gas industry is on the peak. There are many ideas and developments waiting for implementation or ongoing. Most of the literature for the thesis was easily accessible through internet and books. Though, the writer finds that it was very challenging to find information about DOI-IO directly from Oil business related companies. This happens probably because there is no desire to share innovative ideas.

7 Conclusion

The objective of this thesis was to examine the Visualisation Technology in Oil and Gas industry from different perspectives. This project presented point in the visualisation topic in a way to help company with future developments. The result of the key objectives review is presented below.

The thesis has shown that Visualisation Technologies are already widely distributed in Oil and Gas sector. Using new technologies would allow to increase Business value in many aspects. There is a myriad of applications that OOs use in everyday work. All these applications have Visualisation component. That helps in everyday operations broadly. The examples above have shown improvement in productivity, reduction of costs and improvement in HSE. Also, the core challenges have been mentioned. All cited above applications work mostly without binding to each other, covering only some specific parts of Oil Platform life.

The chapter 4 considers DOI-IO. The digital platform has been observed in general and from company perspectives. That's a huge amount of work has been done by Norwegian government for DOI-IO implementation. Almost all OOs have development in this area. As they seek to cut costs and improve effectiveness, this approach may improve not only new platforms, but also upgrade existing platforms accordingly. Implementations are expected soon.

The third objective is a main one. Thesis has shown, that Visualisation creation is a complex process. There are a lot of conditions and requirements that must be implemented for successful visual interface in Oil and Gas industry. Also, there are a lot of challenges that need proper decisions. A variety of data formats lead to a loss of efficiency in work and analysis. Data mostly has no appropriate content description. That makes difficult to store and process information. Poor quality data can lead to catastrophic consequences. Usage of "old" software prevents innovation. From user perspective, I was showing several requirements for Visualisation. The effectiveness of Cloud was noted. For understanding the importance of Visualisation Technologies, the SA was described in detail as well. New sources of collaboration have been mentioned with perspectives in using MR, AR, VR. Importance of Intuitive look with several purposes has been elaborated. With the help of the analysed and obtained data and based on the materials studied, an overview of the prospects for the future in Visualisation Technology have been made. It turns out that further development in Visualisation will lead to significant value creation and value improvement.

Visualisation Technologies has a huge potential for Value creation and improvements in such a complex industry as Oil and Gas. Going from paper to digital resources, using connected data environment, using asset in a smarter way promote changes to model of doing business in Oil and Gas industry. Everything can be faster, better and more accurate.

8 Recommendations for further research

While this thesis is a step to the right direction of analysis of Visualisation Technology capabilities, it contains limitations and prerequisites. Since the aim was to consider the vision, the Data Management component was examined only in the context of creating the user interface. But the Data Management topic is much broader and, in fact, is a case for a separate research. As industry tags only 3% of data and analysed sonly 0.5%, it is obvious that the further research can lead to the significant improvements. That will give opportunity to rethink experience gained and create the ability for accurate prediction in future. Also, that can give opportunity for exact and precise conditions monitoring and faster decision-making.

In turn, insight into VR, AR, M may bring maintenance operations as well as training to a whole new level. It may also allow for dedicated asset operations, or utilization of unmanned platforms. Having that in place would allow significant cost reduction therefore worth a research.

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