PCIC MIDDLE-EAST : Welcome on the Digitalization Route

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Abstract - Digital technologies are today a trend around the planet and across industries. This paper ambitions to go further than the smoke screen and Wahoo effect of digital technologies to dive in the details of applicable use cases in the petroleum and chemical industries. By explaining and analyzing concrete examples of digital solutions, the goal is to present digital as a toolbox enabling better operations.

Our intention is first to explain some wording and concepts gravitating around digital to settle a common ground for discussion. Next, the goal will be to explore the technologies underneath this digital evolution.

The second part will start by defining the Industrie 4.0 prerequires of a successful digital transition for End-Users. Then we will illustrate this technological evolution with the TOP 50 examples of digital use cases in the petroleum and chemical industry. These use cases will be developed, following this standardized structure:

1. Data Capture
2. Connectivity and Formatting
3. Data Operating System
4. Asset Applications – Digital Twin
5. Process Applications – Digital Twin
6. Cybersecurity
7. Augmented Operator
8. Health, Security, Safety, and Environment (HSSE)

I. INTRODUCTION

The digital concept was born in the early 2010s as the application of new technologies to the industrial world. Made possible thanks to the evolution of IT infrastructures, digital technologies take root in the acquisition and treatment of data to create value.

Quickly becoming a trend in all the sectors for communication purpose, the implementation of these digital technologies has been a bit lagging behind. But beyond the trend of the topic lies a real interest for industrials: End-users, Engineering Companies, Contractors, Manufacturers, and Solution Providers.

The digital transition has been rightly labeled the 4th industrial revolution with the trademark Industrie 4.0. After the Mechanization, the Electrification, the Automatization, comes the Digitalization to once more increase production efficiency by saving time and money.

Today, digital technologies should first be remembered for the opportunity they represent: an extraordinary driver for innovation in the petroleum and Chemical industry. With its own challenges and complexity, companies have to approach the digital transition by the right end to be successful. This paper general intent is to pave a way for entities to successfully embrace their digitalization.

The first part of this paper will focus on defining and explaining different concepts, technologies and standards of the digitalization ecosystem. An effort will be made to clarify and delimit the boundaries of each of them for us to all speak the same language.

The second section will begin by listing the general barriers to overcome for an effective digital transition. Then the paper will propose an iterative robust approach to implement digitalization and tackle these barriers efficiently.

Finally and for a practical purpose, the last section will be interested to show the purpose of the digitalization route. Hence, the paper will list and detail the 50 most important Use Cases enabled by digital technologies.

II. SETTING A COMMON UNDERSTANDING FOR THE DIGITAL ECOSYSTEM

If we are looking at the Cambridge dictionary for a definition of the word digital, here it is: [1] "*recording or storing information as a series of the numbers 1 and 0, to show that a signal is present or absent*".

Not to mention that this definition is rather down to earth and may require additional explanations to outline the whole concept behind digital. But as a broad definition in our case, digital would refer to the use of new technologies for industrial applications.

Below are different concepts, technologies and standards important to know for a good understanding of the rest of the paper.

A. Concepts

The first and most important concept is the one of Digitalization. Digitalization, not to be confused with digitization, refers for an entity to the use of digital technology to proceed tasks. Organizations digitalize their activities to develop new services and become more productive. Thus, Digitalization is the result of a successful digital transition. For example, emailing is the digitalization of the mail service, the same service is delivered by a most efficient mean.

Often wrongly perceived as similar, is the concept of Digitization. Digitization is the conversion of any type of information from an analog format (text, sound, etc.) to a digital format. Once digitized, the information is available to be proceeded or stored by electronic devices. For example, a scanner digitizes documents. Digitization is always the first required step to enter the digital world and precedes the Digitalization.

Another concept which is fundamental to enable the rise of digitalization, is the big data. Big data was in fact the pioneer idea to assume that value could be created by examining large database. Using numeric tools, analyses are able to detect complex patterns in dataset and thus create models of interaction between data. These models provide great insights to understand how parameters of a same ecosystem influence each other. The challenge being today to capture gigantic flow of data to form interesting datasets. To be considered suitable for big data, datasets have to respect the 4 V's rule: large Volume, High Variety, huge Velocity and a sharp Veracity.

One central concept serving the digitalization is the Internet of Things (IoT). IoT can be defined as the connection of physical objects to the internet, allowing the communication of the real asset with its virtual representation. This connection allows the accumulation of data corresponding to an asset, required to create value.

A natural concept derived from IoT and crucial to implement digital technologies is the Digital Twin. The digital twin is the virtual representation of a physical process, a physical object or a service. In practice, the digital twin main idea is to aggregate different data to build a consolidated visualization and help making decisions or offer new services. This visualization based on data, can be : a 3D representation of an asset, a dynamic model of a process, or a data centric record.

To run efficiently, digital twin models require large amount of data. These data, sourced by the objects connected to internet, vary by their nature. In the process industry, data can be categorized as Active or Passive.

Passive Data refers to all the information gathered by an equipment related to the physical characteristics of the asset itself, for example: the actuator position, the rotation speed, the cast temperature, the input voltage etc.

Active Data are also captured directly or indirectly by the equipment but go beyond the asset to describe the process. For example: fluid viscosity in a valve, flow in a pump, gas temperature in a pipeline, charge rate of a motor. Both active and passive data are important to build the digital twin of an equipment, a production line, or a whole plant.

The last concept important to get into to embrace the digitalization is the Smart Plant. The Smart Plant is to the process industry what Smart Factory is to manufacturing. Being the final outcome of the digitalization route, the Smart Plant is an heavily connected facility using technology to, not only run the production means autonomously, but also learn and adapt in real time for a greater efficiency.

To perform such wonders, the Smart Plant relies on IoT to connect all the levels of the facility digital twin. Starting by the connection and the digital representation of the smallest pieces (e.g. a captor), it then aggregates to recreate each piece of equipment (e.g. motor+pump), and later recombine layer per layer till the whole plant is connected and modelized by a digital twin. Already source of many values, this achievement can be extrapolated for two additional objectives: connect the plant with other facilities, build the process digital twin.

B. Technologies

As stated from the beginning, the digitalization is the result of the new technology applications. And many fantasies come from new technologies without most people realizing the scope nor the nature of their functionalities. At the lead of these sources of fantasies comes the Artificial Intelligence (AI). The first common mistake is to consider Artificial Intelligence as a technology by itself, when in reality it encompasses a cluster such as: Machine Learning, Natural Language Processing (NLP), Computer Vision, etc.

Artificial Intelligence can be defined as the construction of informatic programs able to recreate intelligent behavior which engage in tasks in the same way as human would do. AI let machines perceive their surrounding environment (physical or not) and interact with it autonomously. AI is not recent but is currently experiencing an incredible acceleration as AI is today able to proceed some tasks more efficiently than humans with a remaining giant room for improvement.

Machine learning is a core technology of the AI cluster. Machine learning is using mathematical and statistical approaches to create models able to learn patterns in datasets. Once learnt, the model is considered as "trained" and can be used in the opposite way to detect the pattern in new datasets. Many algorithms exist each with their own specifications to produce various models and finalities, able to notice for example deviations or churns depending on the need.

Natural Language Processing is also a field of AI where computer science and algorithms are applied to the linguistic field. It gives computers the capacity to read and write in natural languages. Other interfaces are not only limited to read/write functionalities but can also listen and speak to have even more direct interactions with humans. This technology requires a lot of training and a fine configuration as each scenario of discussion has to be learnt by the computer upfront of any comfortable interaction with humans.

After the text recognition, the Computer Vision is another branch of AI dedicated to the recognition of pictures and videos. By acquiring and analyzing visual content, computer vision tries to transform digital images into comprehensive information. The automated examination of the visual content is similar to the one of the human eyes: first detecting geometrical shapes and outlines, then determining the content by a statistical comparison with a known library of element. Computer vision can be used in both ways, understanding the content of an unknown digital image, or as well to detect and categorize events in known ecosystem.

Another technology which takes its origin from the military, is the Drone. Drone can be defined as unmanned vehicles guided autonomously. Drones owe their development to the progress of advanced robotics and high-speed digital infrastructure enabling a real time connection between vehicles and operation centers. For vehicles moving in autonomy the AI is of course a very important technological lock. Drone are mostly perceived as aerial vehicles, called Unmanned Air Vehicle (UAV), but should not be limited to it as Unmanned Underwater Vehicles (UUV), Unmanned Surface Vehicles (USV) n Unmanned Ground Vehicles (UGV) also have many applications in the petroleum and chemical industry.

Blockchain is a technology that has been the center of attention, but which is also more complex to grasp by its function and its usefulness. Blockchain is a technology allowing an ecosystem to store and share information without the supervision of a control center. In fact, it is a distributed data base where information is checked and arrange in blocks at regular time interval. Creating a « chain of blocks », these remote registers are able to secure all the transactions between users since the system was created, making by design the information storage highly secured but also really heavy. Protected by cryptography, Blockchain is a collaborative technology that enables different actors to build trust between each other without third party authority. Not driven by any law, blockchain operations only relies on the protocol users have agreed on. Meaning the management of the information belongs to the selected algorithm.

The last class of technology having a big impact on our industry concerned Immersive Experience. Immersive Experience refers to the digital simulation of a physical world surrounding the user offering interaction possibilities. The two main branches of it are Augmented reality (AR) and Virtual Reality (VR) which mostly differ by their level of immersion in the virtual world. AR and VR are two experiences which have been developed along the last decade with technological similarities but serving different purposes, especially for the industry. AR and VR are leveraging on the same pieces of equipment (mostly headsets, tablets, smartphones) and technology bricks to engage users in a transformed immediate reality. But each technology differs from their level of immersion.

Augmented Reality (AR) can be defined as the superposition in our field of vision of virtual elements over the reality we are facing. The goal is to « Augment » the reality with additional information relative to what a person is seeing.

Virtual Reality (VR) is the representation of a fully artificial universe where the user is immersed in a 3D world where he can « live » through screen and motion sensors. The goal of VR is to position the user in a specific environment to simulate its interactions. While AR will keep the user in his close reality supplementing a layer of virtual objects or information (e.g. data), VR will completely simulate a whole new world for a 100% immersion. This difference modifies fundamentally the user experience and the purposes of AR and VR. While AR technology can be used for a long period of time by operators, the VR experience is limited to short periods of time as the full immersion confuses body perceptions resulting in headaches. Far from excluding one another, both technologies are applying to different scope of the industry, thus should be considered in parallel by End-Users for more efficiency.

C. Standards

It is crucial to approach digitalization like any other type of innovation driver and remember that digitalization is not an end in itself. And as other sources of innovation Digitalization has been codified through standards to be implemented quicker and bring more efficiency in the industrial world. In practice, different series of standards have already been developed to frame digital practices.

Surely the most important standard as being the first digital program to have been initiated worldwide is Industrie 4.0. Industrie 4.0 is the name of the “German Futur of Manufacturing Program”, launched by Angela Merkel at Hannover Fair in 2014. The objectives of this digital program are to maintain the position of the German Industry despite the competition of actors like China, and to strengthen their economy in light of the 2008 financial crisis.

Under the leadership of trade associations (Bitkom, ZVEI, VDMA) Industrie 4.0 has been created with an architecture, communication protocols and standards to connect things from different sources, and design in order to play collaborative. Industrie 4.0 is a standardized approach transverse to all industries which also applies for other sectors like smart cities or e-health.

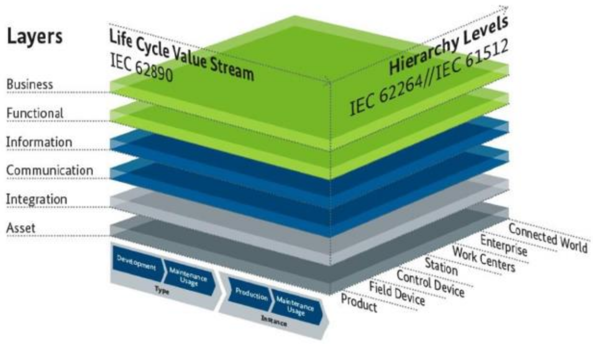


Fig. 1 RAMI 4.0 architecture model

Named Reference Architecture Model Industrie 4.0 (RAMI 4.0), this standardized architecture aligned with the IEC series, uses administration shell as digital interface to connect things together. Industrie 4.0 relies on the Cyber Physical System (CPS) to connect things together and to model a digital twin from a real object. RAMI 4.0 is a standardized approach for: data storage, communication protocols, cybersecurity, functionalities safety, product classification, interface configuration, engineering, and for sure data architecture.

Another important standard which is also transversal to many industries is named OPC UA. OPC (Open Platform Communications) is a foundation composed of industrial companies interested to work together in collaborative mode. Therefore, they created the OPC UA (Unified Architecture) to normalize industrial communications. OPC UA is has a more specific scope than Industrie 4.0 and a opened standard aligned with IEC norm for a better interoperability between IoT devices.

The other main series of standards important to mentioned, as this one is specifically dedicated to our petroleum and chemical industry is called CFIHOS (Capital Facilities Information HandOver Specification). CFIHOS is driven directly by many actors of the process industry, under the governance of the IOGP (International association of Oil and Gas Producers). Still in development, CFIHOS standards’ main goal is to facilitate the communication of information between partners of projects to reduce cost and save time at the design, engineering, construction and commissioning phases.

CIFHOS is a practical implementation of ISO 15926, and is built on the Engineering Information Specification (EIS) used by majors End-Users of our industry.

III. PRE-REQUIRE AND METHOD OF THE DIGITALIZATION ROUTE

Digitalization is high reward, high-cost journey. Turning to new technologies is not only a set of tools to be added in organizations but requires some adaptations. Adaptations not only to the tools but also and mostly adopting new ways of working.

To enter the digital route, entities need to rethink their architecture of digital tools and human power to create the best synergy.

A. Barriers and Pre-requires

Far from its usual understanding, the digitalization route is not a technical issue. Most of the technologies are already available for our industry or could easily be developed to fulfill our needs.
No, the issue is not at the core of the technology. Today, the struggle is mostly in the implementation of those digital solution and how to adopt our organizations it. Organizations being used in its broad sense, can be an entity, a project team, a group of multiple companies.

The more complex barrier to digitalization is how to move from a Document centric organization to a Data centric one. As explained earlier, the data and its usage are at the core of the digitalization. So of course, for our industry which is today organize around documentation, it will be a big shift toward data.
Passing from documentation to data usage has a lot of advantages as it answers the problematics of : data inconsistency, workflow inefficiency, design errors, difficult management of change, non-conformity from design and/or procurement, site handover, commissioning, and tool issues.

But it also requires some effort, and mostly to adopt a robust data management system. Data must be located in only one location to be sure everyone is using the same. It is called the single source of truth. The concept is simple but the problem starts when sharing this data.
Having a single source of truth requires tools available like:
-Standards: to all talk in the same language, data format to be agreed from the beginning and aligned with the final user.
-Platform/database: to all share data and exchange information on the same location. Allow co-working and co-design using the same database and tools.
-Integration layer: agnostic module to allow integration of all types of data.
-Data capture: to gather all the valuable data from the asset. After collection, the dataset needs to be analyzed and cleaned

Once in place, all the partners need to know where to access this data, with partners sometimes outside of the organization. Knowing the right to access the data will be different from one data to another.
Most likely, these data may belong to different companies, raising an Intellectual Property's question**.** How to share data between partners properly?

In order to be shared and thus create value, data needs to follow a data governance. The data governance objective is to manage the access rights of the various services in order to respect the collective intellectual property.
At the scale of a database, the data governance rules how and who can access data.

B. The Digitalization Route

As explained through the beginning of this paper, Digitalization is a broad concept able to take different pathways to achieve its goal. In this part of the paper, we will present a path among others which has been proven in several occasions to be successful.

Before jumping on the road to digitalization, it is quite important to set the goals of it, and as such define what is a successful digitalization.
Once again, many expectations can flow form a digitalization project impacting all the step of a project lifecycle. Yet from a general point of view, a successful digitalization projects is a project which has created value for its actors. If a project has failed to create and show it has created value for its stakeholders, then the digitalization cannot be considered as successful.

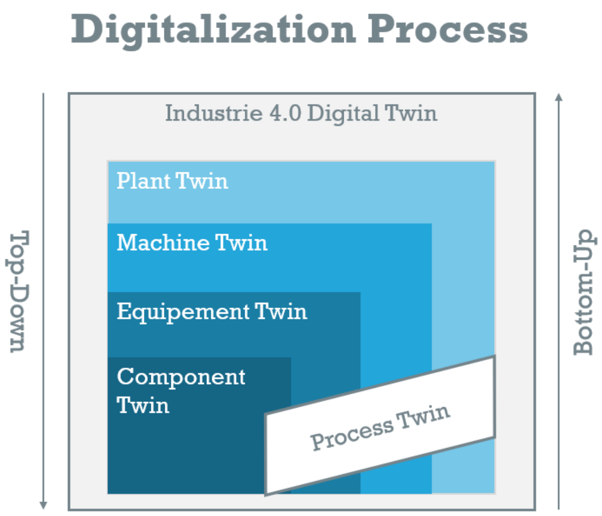
Once the value creation identified in a project, it is important for the leader of a digitalization process to build a robust team and draw a first business model.

It is quite clear today that one single actor is not able to have all the solutions and all the opportunities of digitalization. As such, the digital transformation will happen across all the supply chain of our industry.
For a leader, it is important to build up a strong team to approach the complexity of digital topics. A strong partner in a project will be a company with a strong technological background ready to innovate, and also a company you can trust to share knowledge with. Digital projects will always require the exchange of data and information, which will require a commitment stronger than legal NDAs.
Finding the right partners is not enough, it also important to pay attention to the way the puzzle will be assembled.

The best way to organize the collaborative team is to put in place the correct business model.
A good business model is able to measure the value created by digitalization and transfer part of the value created to the digitalization team. In this sense, Digitalization may require the use of new business models not so common in the energy industry, but which are at use in others.
A good business model will help bring the different partners around the table to start the project, but a correct one will also be able to retain the partners around it.
As such the correct business model is thus the one able to capture part of the value created at the client, but also model the relationships between partners.

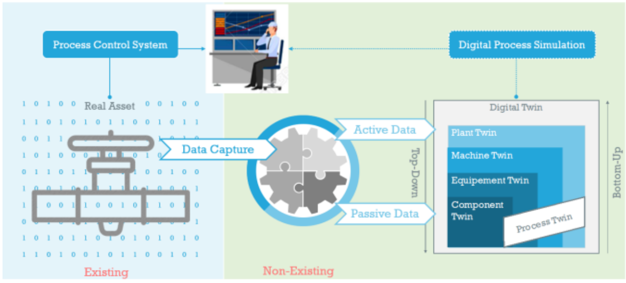
New business models could be explored in the future years, such as leasing of equipment, contract per running hours, etc.
But one thing is sure, once the value identified, the team settled and the business model in place, the technical aspects of the digitalization can start.

Depending on where you stand in the value chain of the process industry, you may choose between two different approaches of the digitalization, the Top-Down or the Bottom-up to tackle the technological aspect of the digitalization.
Both approaches present their pros and cons, but it is important for any of them to keep an agile method and scenarize the different technological resolutions of the initiatives.
Some solutions may be more complete but too expensive, some can be lighter but good enough, etc.



In that respect, the Top-Down approach is dedicated to the End Users and requires investments at the scale of these facilities. This Top-Down approach fits perfectly on new projects, especially in offshore or harsh environment. In these cases, Industrie 4.0 digital technologies can provide End Users with step change in Capex and Opex.
In opposite way, the Bottom-up approach may please all the players of the value chain from the bolt manufacturers to the End User.
It begins with the digitalization of components or small equipment. Then, it escalates to machines, to the process and on last stage at the whole plant. This approach is easy to implement especially on existing facilities. There, it brings quick wins at small risks with great pedagogical value in organizations.
At the end, the purpose of the Top-Down and Bottom-up approaches is to build the digital process loop by one way or another.

As previously said, the digitalization is not the target by itself, it is a mean to create value. The best way to ensure you digitalization process will generate value for the example of operations is to integrate the operator vision of a Digital Process Loop.
In the picture below, we illustrate how to build the digital process loop in parallel to the usual process control system loop.



Compared with the existing conventional process control loop, the digital process loop provides End Users with three key major benefits.
First, it offers far shorter response time, then it guides the operator straight to the root cause, finally it allows to model scenarios for resolution. These capabilities change the game in running large and complex operations.

In the picture above, the idea is to capture most relevant data from the installed base. Then, after a first treatment the purpose is to produce passive data and active data.
The passive data are related to the components and the equipment while the active data translate the process status. The passive data helps to build the Digital Twin of the components and the equipment, then the combination of passive data and active data contributes to build the Digital Twin of the process and the whole plant.

Anyway, collecting these data and treating them to build up the digital loop require multiple competences. Some of them belong to the End User, but most of them standing in its supply chain.
Therefore, creating value from the digital process loop is the results of collaborative process involving key players, in the right business model with the right approach.

IV. TOP 50 USES CASES OF THE PETROLEUM AND CHEMICAL INDUSTRY

Not to stop at the conceptual level of Digitalization, the aim of this paper is also to prove this transition is alive and already happening today.
To do so, there is no better way than explaining an extensive list of use cases already live in our petroleum industry.
In the spirit of the Bottom-up approach, these examples are able to be integrated in greenfield projects and brownfield developments to generate value from new technologies applications.

A. Classification methodology

Classifying the example of true digitalization possibilities is not an easy task but doable. If we approach the digitalization by its filed of application, it becomes doable to list the use cases by categories.
The 8 categories which can umbrella the almost entire digitalization 4th industrial revolution are:

1. Data Capture
2. Connectivity and Formatting
3. Data Operating System
4. Asset Applications – Digital Twin
5. Process Applications – Digital Twin

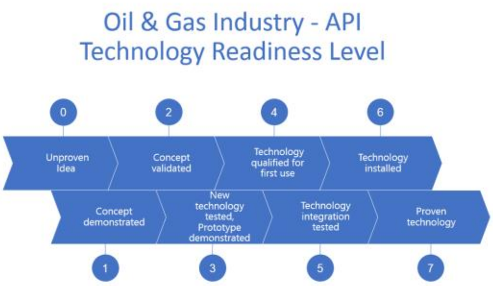
6. Cybersecurity
7. Augmented Operator
8. Health, Security, Safety, and Environment (HSSE)

For the following use case we are going to detail, we will also try to classify them into those 8 categories for a better understanding.

We will also go further by trying to rank the project phase of application of the Use case. The different possibility being : Design, Engineering, Construction, Commissioning, Operation, Decommissioning. Some use case will only belong to one of the project phases, while some other may be transversal to several phases, or even all of them.
A third argument appearing in the classification will be the maturity of the use case. For the rating, we will use the Technology Readiness Level (TRL) methodology.
Technology Readiness Level (TRL) is a methodology to estimate the maturity of a technology. Based on observations, formulations, experimentations, and running feedbacks the TRL approach is used to position the progress of a technology on a scale ranging from Unproven idea (0) to proven technology (7).

First used by the space and military sectors, the TRL was adopted by the European Union in their framework program Horizon 2020 in order to boost innovation. This means that any technology can apply for specific funding based on its Technology Readiness Level.

There is also a more marginal definition of the TRL especially designed for the Oil & Gas Industry based on API recommended practice, as shown below. Scale we will use.



B. List of Use Cases

From all the fields of applications for operators of Digitalization, an overview can be drawn from the following list. Those are concrete use cases using the digital technology available as of today's date:

1. Project design – Cat 4 – TRL 5

A process in which each digital twin types are utilized to design, engineer, plan and execute the construction of a complex project. The data centric twin allows a data centric project organization, guaranteeing the data uniqueness to all the partners, for more accuracy and efficiency in the design and engineering phases. In parallel the mathematical model enables to pre-simulate the process of the project, thus minimizing mistakes or defects in the project being built, providing confidence that quality requirements will be fulfilled. The 3D digital twin (DTW) with the time dimension (also known as 4D) is also a powerful visualization and communication tool that gives a project team much better understanding of project milestones, schedule, and construction plans. Moreover, this project design approach allows an operator step by step validation. Taking advantage of information stored in the DTW to help validate progress as well as ensuring that the operator intent for the facility is being honored both conceptually and contractually.

2. Asset performance – Cat 4 – TRL 7

A process in which the mathematical DTW is used to optimize the performance of an asset (e.g. a pump, a motor, a catalyst, etc). This optimization may have different objectives such as minimizing the running cost, maximizing the life expectancy, maximizing production, preventing downtime.

3. Process performance – Cat 5 – TRL 6

A process in which the mathematical DTW is used to analyse and optimize the operations of a real-world process over time. The act of optimizing the process requires a model to represent the key characteristics or behaviors of the selected physical process, to find the best suitable configuration of production, given the environment conditions. Thus production configuration can be adapted in real time to reduce the cost, maximize production, or increase margin. The process performance use case can be considered at a train level, a plant level, but also at the size of a grid if multiple plants are connected on the same network.

4. Predictive maintenance – Cat 4 – TRL 7

A process using the mathematical model of an asset to anticipate the failure of an equipment. To stave off asset downtime, real time operational data are constantly compared with historical data of the same asset to detect deviation from the normal cluster of working points. By combining all the data coming from the asset and its environment, the DTW is able to detect weak signals way before any usual threshold alarm warnings. This early detection gives time for the operator to react, as the asset can still operate for a while, and find the best maintenance solutions which will satisfy both the operator and the client at the lowest appropriate cost.

5. Local Predictive maintenance – Cat 2 – TRL 4

In the same spirit of the previous use case, this one has the same target of capturing data and looing for deviations. Yet, the architecture of the solution differ because in this case, the system use captors and intelligence for the treatment of the data generated directly on the spot. Also referred as edge computing capacities, those captors are able to capture data, analyze it, detect a deviation, and alert the operators all on the equipment location.
Less complex to implement than the all integrated solutions for predictive maintenance, local predictive maintenance is an efficient way to increase the operability of a plant quickly and at a reasonable cost.

6. Operator Training Simulator – Cat 7 – TRL 3

A process in which the 3D DTW is used for creating images, diagrams, or animations to introduce and train operators virtually. Visualization through virtual imagery has been an effective way to communicate perceptions of plants to operators and recreate concrete installations. Used to familiarize operators with sites and maintenance operations, the DTW enables a closer monitoring of training sessions in the comfortable environment of offices for a share of the cost. The development of augmented and virtual really also supports advanced visualization.

7. Equipment installation – Cat 8 – TRL 4

A process using the 3D DTW to perform a spatial analysis on the plant. Considering the perceivable architectural elements with their boundary, the DTW is able to stress the feasibility of an installation.

Meaning the solution will be able to simulation the physical journey inside the plant of each equipment and can advice on the order of the installation steps. Thus preventing the situation of a large equipment unable to be installed because it does not pass in the alley of the plant.

8. Process simulation – Cat 5 – TRL 4

Simulation requires a mathematical model of the DTW to represent the key characteristics of the process when the real system cannot be engaged itself. The model represents the system itself, whereas the simulation represents the operation of the system over time. Simulation can be used in many contexts, such as the research of new operational configurations for performance optimization, validate engineering solutions, new equipment integration in the process, and evaluate production costs. Simulation is also used with scientific modelling of engineering designs to gain insight into their functioning.

9. Scenario anticipation – Cat 5 – TRL 3

Scenario anticipation is a use case linked to process simulation, as it is used to show the eventual real effects of alternative conditions and courses of action. Based on the process simulation, scenarios can be useful to prepare turnarounds, shutdowns, equipment failure, safety plan and choose the most efficient script.

10. Virtual visit – Cat 7 – TRL 5

Virtual visit is based on the 3D DTW and has different values depending on the user. For people on site the value would be to learn how to evacuate from any location, or where the emergency system is located (Emergency System Device : button, phone, extinguisher). For project managers the virtual visit is useful to analyze the construction of complex system as a tool for design reviews at all along the project life.

11. Root cause analysis – Cat 4 – TRL 6

A process in which the DTW can be used both front and backward to find the causes of an incident. Frontward, because the existence of deviations between the digital and real twins can enlighten the causes of an incident. Also frontward, the absence of deviations may suggest a design error or an external factor, as the system has been operating according to its command. And backward, because the model can be used as a reverse engineering tool to establish the inputs of the incident.

12. Existing plant modifications – Cat 4 – TRL 6

A process in which the DTW is used during the design and construction process to identify and coordinate potential process/space conflicts by evaluating the model of the existing system with the integration of the new modification. During modification design the goal of clash avoidance is to ensure there is adequate space or process flexibility to fit all designed modifications in the existing plant.

13. Remote operating – Cat 5 – TRL 4

The DTW model of the equipment/plant behavior is requested to decentralize the decision-making process. This decentralization can have two aspects: either the control room is outsourced from the plant location to send high level requests (e.g. start/stop, production setpoint); or the equipment/plant becomes fully automated and decisions as well as commands are made from a different location (e.g. subsea operations).

14. Document management system – Cat 1 -TRL 7

A platform based on the data centric DTW to gather, centralize and organize all the documentation and information from internal and external sources, regarding the project to guarantee the unicity of data and constant update of documentation. Such a system increases the accuracy and the efficiency of the project team for design, engineering and optimization of asset installation. The document management system facilitates the access to manufacturers information, from a product library in a machine-readable format, promoting interoperability. The equipment library will mature to ultimately include not only graphic and spatial information but also information related to technical specifications, engineering capabilities and tolerances, first cost, Total Cost of Ownership, location in the plant, maintenance and repair, environmental, mean time to failure, as well as installation, warranty, and any other information pertinent to the equipment for suitability in a designed facility. It may also include performance information, or relationship with other pieces of equipment and other information which could bring value.

15. Smart information platform – Cat 3 – TRL 6

Production of information reconciliation, information sharing with third parties for maintenance, availability for open innovation.

Smart information platform is the main tool to be used for centralizing data in the approach of a data centric organization. Those platforms can be many, one hosting the equipment operational data, the other hosting engineering and design information. Usually these platforms are the interfaces to access data stored in clouds solutions.

16. Operation readiness – Cat 5 – TRL 3

A process gathering the different types of DTW to allow a smooth handover between commissioning and operation by ensuring all data to be transferred (e.g.

As Built documentation, spare part list, MMS data population, etc) from the hands of the engineering company to the operator. Work follow-up, quality, welding, pointing, precom, Data management for decommissioning; every nature of data is concerned in this handover to verify all subsystems just prior to commissioning to ensure operator requirements as intended by the owner and as designed by the building architects and engineers are met.

17. Design replication – Cat 4 – TRL 6

A process in which all the DTW types are exploited to satisfy the approach: design one, build many. Accumulating all the technology bricks of multiple already designed projects, the concept is to capitalize on the hard benefits for next upcoming projects by replicating previous solutions to new projects, saving time and mitigating risks.

18. Asset pre-qualification – Cat 4 – TRL 2

In the same spirit than previous use case, the use of historical data can be used at the level of a project but not only. In the case of the specification's pre-qualification, the goal is to pre-writing project specifications for assets due to comparison with previous projects which are similar.
The idea of this use case is not new as many contractors re-use their previous specifications known proven to save time and capitalize on its experience. But in this case the digitalization changes the scale of this practice. Usually, it is something by project engineers who have looked into their own previous experience. With an AI solution, the spectrum of references to be used is way broader and can capitalize on the entire project background of engineering company.

19. Laser scan for design digitalization – Cat 1 – TRL 7

Laser scanning is a technology developed in the 90s for the digital reconstruction of existing assets.
Laser is able to measure the 3D environment with an high precision and then reconstruct the DTW of a plant as it is built. Those technology are really well fitted to obtain the DTW of brownfield plant easily and at a small cost. Yet the limitation of this use case is it only rebuilt the physical 3D model of the plant, and not its process which usually need to be manually added later on.

20. Robot operations – Cat 4 – TRL 4

The basic concept is to have routine maintenance operated by robots and not humans. Especially interesting from the safety and cost aspects, unmanned operations technology key is the 3D DTW for robots to be able to locate themselves and move on site. Robots' objective is double; first execute repetitive tasks to free more time for operators on complex tasks, second to intervene and replace humans in high-risks environments.

21. Electrical network supervision – Cat 5 – TRL 7

A process by which the DTW is used to determine the most effective electrical engineering design based on the specifications. The performance simulations can significantly improve the electrical design of the facility and its energy consumption over its life-cycle. A close monitoring of the electrical network performances and its DTW also reduce downtimes.

22. Installation monitoring – Cat 7 – TRL 4

A process using drones and DTW to measure the position of every piece of equipment in an installation and validate that construction is in accordance with the plan. This approach is used to rapidly capture the real shapes of objects, buildings, landscapes and detect a deviation from the digital 3D model. By comparing both, the system is able to avoid space clashes at a really early stage and reduce corrective costs.

23. Heat detection – Cat 8 – TRL 6

Heat detection use case is the perpetual monitoring of the different temperature points of a plant using a drone. The drone flies around the plant routinely and is equipped with a thermal camera. Always filming the same equipment at the same timing, AI solution can easily detect any deviation in temperature points compared to previous routine measurement.
No need to adapt the plant, the drone can be installed easily and monitor large infrastructure, giving alerts only when needed.

24. Local gas leak detection – Cat 8 – TRL 7

In the same way drones are used for heat detection, they can be used to also detect gas leak into a plant. Based on ultrasound imagining device, the drone can routinely fly around and film the operating equipment. The post-treatment of the film can detect any gas leak in the process and thus call a warning for operators to into action.

25. Global oil / gas leak detection – Cat 8 – TRL 7

Some ONGs and offshore operators have developed the technology to detect oil and gas leak offshore. Based on satellite analysis of images and laser beams, we are now able to detect at early stage any beginning of petroleum leakage, especially in offshore condition. This detection is also useful once the leakage has been detected to follow up the evolution of leakage during the mitigation and prevent any oil spill to damage the sea.

26. Intrusion detection – Cat 8 – TRL 5

Based on AI and security video system, the intrusion of external elements humans or not can be detected automatically.
The security of Atex plants being critical the automation of intrusion detection is a must to ensure the asset safety. Those automatic system are more efficient in safeguarding the safety of the are.

27. Underwater Robot maintenance – Cat 7 TRL 5

Drones can fly but they can also swim. In this case, the idea is to use drone submarine to operate maintenance routine tasks underwater. Divers cannot operate in many conditions and not everything can be done above sea level and then sunk. Thus, robot submarines have been proven quite useful in helping underwater maintenance.
Those robots are often referred as UUV Unmanned Underwater Vehicles.

28. Connected stock management – Cat 2 – TRL 6

Connect stock management is a digital tool able to aggregate all the inventories of a company and its suppliers. All the inventories become available to the operators with the immediate effect of accelerating mitigation of downtime by knowing where to look for a spare. Those connected stock management tool have been enable to function because of AI programs able to rebuild one database from several ones with different nature and storing locations.

Moreover, this connected inventory also has the advantage of offering you a flexibility in case the spare part missing by providing to operator a complete view in the comparable spare parts that could fit to maintain the process while looking for the best fit.

29. Storage management – Cat 2 – TRL 7

Software for storage management have been around for many years but the development of AI technology has changed their usage for the best. In fact, today AI are able to predict the future needs in term of stock. For example, once they are connected to ERP, they are able to order the spare parts for intervention coming and send a warning if the equipment needs has not been delivered yet.

30. 3D printing for new design – Cat 4 – TRL 3

3D printing enables many possibilities. One of them is the capacity to manufacture new design. For example, some designs have never been achievable for interiors of valves because of manufacturing technology not being able to produce the shapes. With 3D printing, especially of metal, new shapes can be manufacture. Ball valves with inside out parts, are new designs which prevent leakage and are more efficient in term of performances.

31. 3D printing for faster maintenance – Cat 4 – TRL 3

3D printing has evolved so much on the last few years printing machine have become a commodity. A new use case has arisen investing in 3D printing machines to replace expensive inventories of spare parts. In a case of downtime in a remote area due to an equipment failure. It becomes cheaper of course quicker to have a 3D machine on the spot and print the equipment needed, compare to waiting for a part to be shipped, sometime offshore. Thus, the design of the part can be sent via internet and printed for replacement in the same 24 hours.

Thus the replacement of the part is quicker, reduce the downtime cost, and it also save the transportation cost in emergency.

32. Operator connection to expertise – Cat 7 TRL 7

Equipment and their operations are become more and more complex, to the point where even with knowledgeable operators some maintenance or defect are too complex to handle.

All the operating companies have experts in their fields, but they are rarely in the good location when a problem occurs. With new technologies and fast internet connection, operators on the field can connect via visio applications to experts around the planet and benefit from their expertise to save situation.

This usage have several benefits. First, it enables critical operation to be done faster and better. Second, knowledge is better shared between operators and experts. And third, you can capitalize on the recording of those video to create digital learning centers of those operations.

33. Operator remote data access (read/write) – Cat 8 – TRL 5

Operator are in front of assets all day long but rarely have access to the information of those assets in the same spot. Thus creating situation of back and forth for operators to get the right information sheet close to the equipment.

With the new technologies, more and more equipment are tagged with a QR code to access their documentation. Thus operators can access via tablets all the updated information of the right assets immediately and remotely to smooth their actions.

Those tablets can also be used to collect the information about the maintenance detail to aggregate in the DTW the data about the lifecycle of the asset. Operators are then able to read and write data in shared databases.

34. Operator gas exposure – Cat 8 – TRL 7

The well being and safety of staff is the primary concern of all End-Users. More and more operators personnel are evolving to the augmented operator, and if it often refer a tablet, we forget about the new generation of safety device.

The fist safety device to integrate their smart vest is a connected gas exposure captor. Not only it warns the operator of its exposure, but it also sends the alert to the control room for more safety.

This device also has a passive usage for which it measures the density of all the harmful gases during the routine of operators. The treatment of those data can thus detect an increase, even if not dangerous yet, of gas density in the plant.

35. Operator fall tracking – Cat 8 – TRL 5

In the same spirit of the previous use case, the idea is to tackle the fall of operator while on maintenance. Given the density of equipment lying all around plant, it may happen for operator to tribble and fall despite the care and layout. Thus, operator are starting to be equipped with fall detection devices. The main objective is to prevent an injured worker to go unnoticed for a long period of time in plants that can sometime reach 10km², increasing the seriousness of the fall.

36. Operator position monitoring – Cat 7 – TRL 6

Thanks to the new technologies, operators position can be monitored in different ways : GSM, satellite, wifi, Bluetooth or Lora. Knowing the position of operators can be a efficiency, a safety and emergency need.

An efficiency need first, because during the day, it can be more flexible to allocate tasks to the operators nearby and optimize the distance they need to walk through the plant. It brings less walking around and more time spend on maintenance tasks.

A safety requirement also, because for the wrong reasons it may happen an operator being in a zone of danger (gas leak, electric arc, turbine restart, etc) By having the live position of all the workers, the control room can be sure of the safety assessment. This

requirement is even bigger for the personnel offshore that can fall in the water. Their position monitoring is of course essential and has been greatly improved with satellite and long-range communication protocol.
And finally an emergency need, because in case of explosion, the positioning is the only useful data to manage the human collaterals.

37. Chatbot requests to operators – Cat 7 – TRL 4
As part of the augmented operator, a tablet is often the first equipment added to the personnel doing maintenance. As stated in use case 33, the access to data is a most for them to work correctly. To make their life easier, a chatbot can be added as interface for the tablet to dialog with the operator. It allows the operator to ask information and then the chatbot trained via an AI can look for the right data to communicate, while the operator has not stopped his focus on his task. The operator can use the tablet hand free and without needing an eye contact.
Maintenance are thus carried out faster and operators can achieve more complex tasks.

38. Video tracking – Cat 8 – TRL 6
Video tracking is the superposition of AI software on security videos. AI are now able to analyze live image and detect patterns of events. Those events can be many : explosions, intrusion, fall, etc.
Digital tools have been proven more efficient in detecting known events, as they can analyze an unlimited number of cameras recording, while humans are loosing focus above 16 screens.
Those digital tools can go beyond the detection and launch the next step. In the example of an intrusion, the algorithm can send the warning to the security team with the location and number of people.

39. Offshore drone delivery – Cat 7 – TRL 2
Offshore platforms or FPSO have regular need from onshore and usually the rotation are done via helicopters. But helicopters being expensive, more and more operators are looking for drones UAV, under the shape of small helicopter to do the routine rotation of delivering food supplies or spare parts.
More than reducing the cost, it also reduce the risk of helicopter pilot and can enable more frequent rotations, and quicker response for spare part as well.

40. Advanced oil and gas exploration – Cat 4 – TRL 5
Exploration has always been a complex work of geology data analysis. And in term data analysis, the latest generation on algorithms have become more powerful than experts, even without training at detecting patterns. Thus some exploration IOCs are crunching their historical data of exploration, including their discoveries. Some of them are now able to detect oil and gas reservoir precisely, enabling future campaign of exploration to be analyze automatically with better chance to identify future fields.

41. Advanced oil and gas recovery – Cat 4 – TRL 7
AI softwares can be used to detect fields, but they can also be used to optimize the production of those field by simulating the fluid mechanic all along the field life cycle. The largest computers of the world were already at work 20 years ago to determine the best EOR strategy. But with the cloud technology, calculations can now be made by farm of servers and enables another type of calculation because AI can now explore all the possible scenarios and select the one which could be the quickest, the one requiring less energy, the one extracting the biggest amount of product.

42. End-client demand monitoring – Cat 5 – TRL 2
Supplying the right amount at the right moment is always a difficulty for process plant managers, thus some of them are turning to satellite information to estimate the future needs of their customers.
A good example would be the hydrogen gas provider who analyze the volume transported by the ships arriving to its neighbor refinery. The volume of crude arriving to be unloaded is a good benchmark of the hydrogen volume which will be needed in the coming days.
By accessing that information via satellite and AI, the hydrogen provider can optimize its production and save costs.

43. Remote internet connection by satellite – Cat 3 – TRL 5
Internet connection via satellite is nothing new, but it is still so expensive that only in rare occasion it can be used for offshore installations. With digital technologies, more and more data are needed but not all of them need to be shared on the cloud. Lately, digital technologies are more and more implanted on edge, meaning on the location of the data capture. Thus, the treatment of data is done on the spot, reducing incredibly the volume of data to be sent via satellite. This remote internet connection is then only use for selected information creating high value. So it becomes profitable to connect offshore installations to internet.

44. Chemical protocol R&D – Cat 5 – TRL 2
The petrochem industry is becoming more and more complex with new need in term of carbonate product, like SAF, urea, hydrogen. And at the other side of the spectrum, new feedstock needs to be explore to produce carbon product like CO2, waste or plastic.
New inputs products and new outputs needs call for R&D to develop newt processes. But the complexity of those carbonate reaction are becoming too high for a human mind to handle. Thus, some lab are turning to AI to invent tomorrow processes and start digital trials of chemistry.
With some good results now in industrialization phase, like domestical waste to hydrogen processes, those new type of R&D are now depending on digital technologies.

45. Responsive planning and downtime scheduling – Cat 7 – TRL 6
Organizing downtimes in a plant for maintenance is a complex task to optimize the work done and reduce as maximum the period without operations. Yet, it is even harder to follow the execution of said tasks.
To help plant manager deal with those tense time, new softwares have been developed which can build the most efficient timetable given the tasks and their links. Thus, the planning is optimized, the execution of

of the tasks can be followed with a high granularity and if any deviation comes up during execution, the software can update the schedule with the new constraints.
On top of those earnings, you can also from one maintenance to another capitalize on the plannings used before and use the lessons learns.

46. Product quality tracking – Cat 5 – TRL 4
Capturing information about equipment is easy but capturing data about the process is a bot more complex. In the layers of the DTW, the process information are maybe the more important ones as it enables you to build some knowledge about the product passing through your plant. Capitalizing on those data, you can use your historical data to determine the condition of the oil or gas passing being processed. This capacity is really important especially for petrochemical activities because it enables you to always have the best purity of products at your output. It means more value crated from raw material and no losses from bad batch.

47. Ship self-positioning – Cat 5 – TRL 4
Ships positioning for tankers/FPSO/FLNG is a complex task combining automation, marine, propelling, and geospatial skills. Those systems have been optimized when AI softwares have been plugged to the automation in order to learn from historical situation.
Based on the past behavior of the ships in all the previous condition, the AI is able to better position the ship while consuming less energy. In some cases, the savings in energy have been to the extend of 10%, for being more static and less mechanically constraining.

48. Ballast Management – Cat 4 – TRL 6
In the same spirit of the previous use case, the usage of AI algorithm has bring optimization to complex processes. The ballast management is one of them as it combines flow dynamic, with fluid dynamic, and mechanical engineering to stabilize ships.
This stability is a crucial challenge has it increase the safety and performance of ships. Thus, using AI to manage the flow of water can save money while increasing the performances and rentability of the asset.

49. Blockchain: product and asset certification – Cat 3 – TRL 4
Blockchains have many uses but in our industry the only use case which have been today proven is to use this trustful process to certify the right authenticity of assets. Between the production site of the equipment and the plant location many things can happen. Thus using a blockchain can guaranty the right origin of the assets being installed as well as the validity of their ATEX certification, for example.
Thus the shipment does need to be too looked after, as the blockchain enable the verification to be undoubtful.

50. Extended enterprise – Cat 6 – TRL 3
The extended enterprise is the concept of a high level collaboration between entities working on a project, for the project benefits. This collaboration can be seen a mutualization of the digital services which are shared between all the partners of the team. Softwares are shared on premise, data are shared, digital services are also shared to connect people together on the same floor.
At smaller scale of projects, extended enterprise and agile method have been proven more efficient in the delivery time of projects, as well as the need in resources to achieve the same result.

NOMENCLATURE

IoT	Internet of Things
AI	Artificial Intelligence
NLP	Natural Language Processing
UAV	Unmanned Air Vehicles
UUV	Unmanned Underwater Vehicles
USV	Unmanned Surface Vehicles
UGV	Unmanned Ground Vehicles
AR	Augmented Reality
VR	Virtual Reality
Bitkom	Bundesverband Informationswirtschaft, Telekommunikation
ZVEI	Zentralverband Elektrotechnik- und Elektronikindustrie
VDMA	Verband Deutscher Maschinen- und Anlagenbau
RAMI 4.0	Reference Architecture Model Industrie 4.0
OPC UA	Open Platform Communications United Architecture
CFIHOS	Capital Facilities Information HandOver Specification
IOGP	International association of Oil and Gas Producers
ESI	Engineering Information Specification
DTW	Digital Twin

V. CONCLUSIONS

“Data is the new oil” 2006 is a well know quote, but what if you were having both?
This is the underlying question we answer in this paper as we tried to prove that the Digitalization Route is no more a dream but an actual path for innovation.
Operations in 10 years from now will be data driven and the question is more about, will you part of it and be a link of the digital chain, or will you miss the 4^{th} industrial revolution.

In this paper we started by trying to show the genesis of digital technologies and trace their applications to our petroleum world. Always trying to share knowledge the last part of this paper shew the possibilities of usage of those new technologies down to our operations problem in order to produce the same energy, just better.

VI. REFERENCES

[1] Cambridge's definition of Digital

VII. VITA

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