# Digital Twin : What is this animal?


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Cécile GAUDEAUX
AIR LIQUIDE
57, avenue Carnot
94503 Champigny/Marne
France

Jean-François RAUCH
AIR LIQUIDE
57, avenue Carnot
94503 Champigny/Marne
France

Jean GUILHEM
2B1st Consulting
943 route des Pècles
74400 Chamonix
France

***Abstract*** - Digital twin (DTW) is today a buzzword in the industry and everyone has a different understanding, comprehensive definition of what it is and what it is for.
The purpose of this article is to explain/define what is a digital twin, to introduce the different types of DTW, with some illustration (aerospace & building).
In a second part, the prerequisites in an engineering organisation to reach the maturity of being able to do a DTW are described (integrated tools, data driven organisation…) and how to manage DTW during a project execution (from front end engineering to hand over to operation, with the added complexity of change orders).
In a third part, the document will focus on digital twin usage for industrial operation:

- What are the customers/operation expectations from engineering : easy single access to the complete project documentation (3D, 2D, process and technical specifications, operational manual, maintenance data and PM linked to MMS...), and to the process simulation part,
- What needs to be done for the real time process modeling part (with real time data acquisition and real time data reconciliation)

## I. DEFINITION OF DIGITAL TWIN

The first part of this paper examines the different concepts hiding behind the DTW and delimit the boundaries of each of them, with examples from other industries.
The next section explores what are the impacts of the DTW when it comes to engineering and what are the pre-requires to extract all the value from this concept. The final part of the paper is intended to be practical by briefly listing a series of use cases tackled thanks to the DTW, and the detailed explanation of the real time processing example.

Since the beginning of the digital transition era, the DTW concept has attracted a lot of attention, becoming a catch-all idea without clear boundaries.

As operators' core activity is to run assets, the DTW comes as the natural common base to support digital initiatives. For operators willing to embrace new technologies, the DTW appears as a pivoting point of their digital transition.

As a broad definition, DTW is the virtual representation of a physical process, object or service. In practice, the DTW main benefit is to aggregate different data to build a consolidated visualization and help making decisions or offer new services. This visualization can be a 3D representation, a dynamic process model, or a data centric twin.

Moreover, the DTW is not a sedentary animal as it should follow the whole life-cycle of its real twin. From the design phase to the decommissioning, the DTW will grow by the aggregation of every data affiliated to the physical system it is entitled to represent.

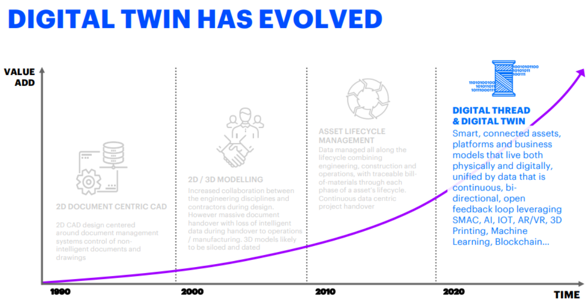


Fig. 1 DTW maturity over the last decades

The DTW concept applies to all the existing layers of assets/processes in a plant. Mapping the data interactions between layers of physical assets, the DTW will gather data to numerically recreate the digital replica of a system. From these interrelations, we understand the challenge of DTW is to collect, aggregate and use data from different sources and various natures. Thus, to let people and objects from different entities talk to each other, the DTW requires standards to align its actors.

In practice, different series of standards have already been developed to frame digital practices. The first of it to be developed and implemented, has been the RAMI 4.0 (Reference Architecture Model Industrie 4.0) [1] by the ZVEI, based on ISO and IEC standards. In this example, the DTW relies on a three dimensional map to connect things together, as seen below.

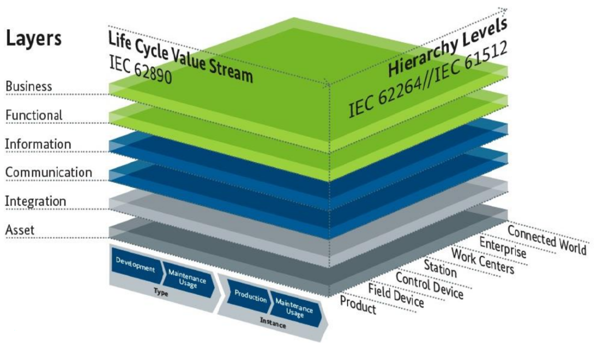


Fig. 2 RAMI 4.0 architecture model

The other main series of standards called CFIHOS (Capital Facilities Information HandOver Specification) [2] 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.

## II. TYPES OF DIGITAL TWIN

DTW is a general denomination for an umbrella of solutions. Depending on the final objective of the solution, different types of DTW can be built:

1. 3D Model
   In this case the DTW objective is to recreate the physical characteristics of an asset. Meaning, the model should integrate information about the structure of the asset, being the shape, color, material, weight, position, motion. Use cases relative to this DTW include: operator training, maintenance test, operability study.
2. Data centric Twin
   All data referring to the design, specification, proposal, detail, or maintenance manual. The current practice is a 2D model: PIDs with links to all related documents/data.

   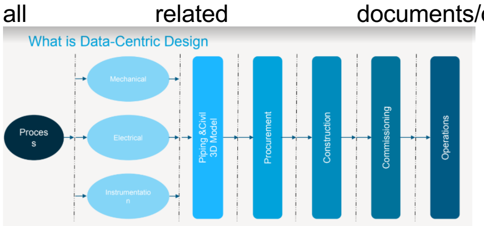
   

   Fig. 3 Organizational layers of a Data centric approach
3. Mathematical / Physical model
   In this case, the objective is to go beyond the physical aspect and consider its operating logic. Meaning, the model recreates the patterns of interaction between the variables of the digitized assets, either in steady state or in dynamic. This model can be drafted from the equations ruling the physical phenomena happening in the asset. Use cases relative to this DTW include: predictive maintenance, scenario anticipation, process simulation.

One often assumes that DTW is only the business of a new build plant, in fact it is also applicable to existing facilities. Considering the life-cycle of the plants in the petroleum industry, it would be a shame not to apply the technology to existing plants, even if it may have a different extent.
For new plants, the DTW is updated and used all along the complete life cycle of the asset/process it represents. In this case, the DTW will start to be specified from the design phase, then be continuously updated until handover to operators, to finally also be edited during operations and end of life.
For existing plants, the DTW may not have been built since the initial steps of the project development. Yet a DTW can still be implemented, at least partially, through the reconsolidation of the data available in the documentation, running data, and 3D scan.

## III. ILLUSTRATIONS OF DIGITAL TWINS

DTW takes different shapes depending on the industry and the use case to tackle. Here are presented three DTW coming from other industries, with their underlying technologies.

### A. *NASA Spaceship*

Today NASA is using the DTW under its Data centric twin version to develop the optimum equipment. NASA motivation is to design, build and test every piece of equipment digitally before manufacturing for efficiency and safety purposes. The designed system has to fully operate accordingly with required performances before being manufactured. After production, the physical asset is connected to the DTW once again to check and validate operational behaviour. This application combines different clusters of technology, such as:

1. Big Data
   Gathering and reconciling data from multiple sources working in collaborative mode on the development of equipment to guarantee the data update and unicity.
2. Digital Infrastructure
   A robust information system is required to manage the data and the accesses of the cloud system. The data architecture also calls for a high level of data standardization on the project.
3. 3D Printing
   Useful for prototyping pieces of equipment or for manufacturing complex geometries, the 3D printing technology enables new manufacturing possibilities.
4. Blockchain
   In the matter of certification and control, NASA started to use blockchain to trace its equipment all along the lifecycle.

### B. *Autonomous Vehicle*

An autonomous vehicle is able to understand and perceive the surrounding space in order to actively interact with moving objects or people, and drive itself without human input and the need to change or modify the environment. According to our definition, this case corresponds to a 3D Model of DTW. It combines different technologies belonging to four main clusters:

1. Internet of Things
   Both long- and short-range are required for the system to localise itself in real-time, or to exchange information in connection with other vehicles/infrastructures.
2. Machine Learning
   The vehicle needs to develop an intelligent vision to detect interactions from its environment. This intelligence is learnt from Big Data analysis and algorithms training.
3. Digital Infrastructure
   Extensive data storage and data processing are required for the analysis, especially the Fog/Edge Computing to reduce latency and obtain real-time response.
4. Robotics
   The full automated vehicle can be viewed as a drone itself, meaning a robot, as the connexion can also be made to receive instructions from a remote pilot.

### C. *Smart Building*

For a few decades, all buildings are designed, constructed, operated and maintained using BIM (Building Information Modeling). Online, the following definition of the US National Building Information Model Standard Project Committee [3] details :

> *"Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition."*

After its construction, the same 3D tools are used to deliver traditional services – such as illumination, thermal comfort, air quality, physical security, alarm, waste management, with the lowest cost and environmental impact over the building life cycle. Moreover, devices in the building can be mutually connected and be controlled on premise or in distance by operators and occupants. From our definition, this is a Mathematical/Physical model of DTW. This application combines different technologies belonging to four main clusters:

1. Internet of Things
   Short-Range IoT devices (e.g. smart meters or smart power grids) enable real-time automation, data collection and remote control.
2. Artificial Intelligence
   Including Machine Learning for efficiency related predictions and Intelligent Vision for advanced tracking, object/person recognition and high-level security systems
3. Digital Infrastructure
   Involving cloud technologies for internal and external data gathering, Big Data for real-time analysis.
4. Biometrics
   For occupants recognition to manage buildings accesses.

## IV. PREREQUISITES OF THE DIGITAL TWIN IN AN ENGINEERING COMPANY

The DTW is intended to process data of various natures but interacting between each other.

The idea is to move from a Document centric organisation during the engineering phase to a Data centric one.

It intends to answer the following challenges met during any project execution and provide efficiency in lots of engineering data manipulation all along the project lifecycle: data inconsistency, workflow inefficiency, design errors, difficult management of change, non-conformity from design and/or procurement, site handover, commissioning and tool issues.

**A strong engineering data management** is essential to DTW. We can identify 2 types of Data: Design Data and Time stamped Data which are evolving during the Operation. There is a non-exhaustive list of information that can be contained:

1. Process Data
   Flow, temperature, pressure, composition...
2. PID
3. Mechanical
4. Electrical/Electronics
5. Automation
6. Documentation

The data must be located in only one location either during engineering and operation : **single source of truth.**

Central to the DTW concept is the creation of an asset data management platform.

The data location is something to think about from the start as well as the DMS (Document Management System) to be used. Further tools to be used by project members for data storage, access rights, collaborative platform and dedicated servers where licences pooling is managed must be agreed and well set-up upfront for:

1. Software
   Same software to be used by all teams
2. Safety
   Access rights management and data protection (co-working with partners and contractors to be evaluated)
3. Maintenance
   Critical asset information loaded in MMS,

4. Status
   AFD, AFC, As Built
5. Business
   Collect the data to allow all types of interventions (equipment replacement, maintenance, …) estimation and scheduling.

The DTW data are collected from day 1 of the engineering up to the handover to Operation. Then data will be managed by the Operation team.

Prior to any data collection, data governance must be clearly set-up and in line with customer expectations.

The pre-requisite is definitely having a data integration layer between all tools modules (Process, PIDs, 3D …) ensuring data consistency all along the project life cycle.

### A. *Tools to integrate*

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 analysed and cleaned.

### B. *Data Governance*

By nature, a DTW needs to operate the aggregation of multiple data obtained from different sources. Most likely, these data may belong to different players, raising an **Intellectual Property's issue.** How to share data between partners and how to respect each partner property?

In order to be shared and thus create value, data managed by the DTW needs to follow a strict **data governance**. This data governance objective is managing the access rights of the various services in order to respect the collective intellectual property (workflow to define by who and when the master data can be changed, who should be informed..).

One challenge during project execution is to ensure data consistency between each discipline which are sometimes used to work in silos.

## V. EVOLUTION OF THE DIGITAL TWIN ALONG THE PROJECT

As the asset is evolving along the lifecycle of the project, the DTW needs to adapt and grow. The global data nomenclature may stay the same along the twin life, variable values are expecting to change. The stage of the DTW can be presented as:

1. Product development
   Basis of design, input data to be considered..
2. FEED (Front End Engineering and Design) (if any)
3. Basic and detailed engineering (including procurement)
4. As Built (for handover):
   Update after construction and commissioning completion.
5. Operation and Maintenance:
   When data are loaded in the MMS and in the Scada for "operation readiness" topics.
6. Decommissioning of the plant:
   This topic is more and more considered in the projects (already the case for building and on-going for industrial facilities).

## VI. OPERATORS AND ENGINEERING EXPECTATIONS FROM THE DIGITAL TWIN

The maturation of digital technologies has created a path for the development of new solutions to answer problematics, yet stayed untouched or still unsolvable. The boiling environment surrounding the digital world, with the births of unenumerable start-ups and creation of new offers from usual actors, provides operators with loads of solutions for their business. Nevertheless, even having many solution providers, End-Users still rely heavily on the Engineering companies to integrate these technologies in their operations.

From Project development to Operational excellence, or Health & Safety, the scope of applications of digital technologies is broad for the Oil&Gas industry. Operators have realized the importance of the digital turn happening as it may be a fantastic opportunity for innovation or a massive trap, depending on how the turn is negotiated.

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

1. Project design
   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 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
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
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, maximise 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
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. Operator Training Simulator
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.
6. Equipment installation
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.
7. Process simulation
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.
8. Scenario anticipation
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.
9. Virtual visit
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.
10. Root cause analysis
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.
11. Existing plant modifications
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.
12. Remote operating
The DTW model of the equipment/plant behaviour is requested to decentralize the decision making process. This decentralization can have two aspects: either the control room is outsource 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).
13. Document management system
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.

14. Operation readiness
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.
15. Design replication
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.
16. Robot operations
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.
17. Electrical network supervision
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.
18. Installation monitoring
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.

## VII. REAL TIME PROCESSING WITH DIGITAL TWIN

When the DTW needs real time data, three main steps describe how to convert data to value/information.

### A. *Data Acquisition*

The first step consists in "**Collect**" the data (all field instrumentation, IoT, external data as meteorological data) into a historical record. The acquisition frequency, the accuracy, "compression" parameters have to be properly defined to balance the needed accuracy with the data storage and the transfer rate between local Distributed Control System and record. This record is more and more a cloud (private or not), to make the access easier.

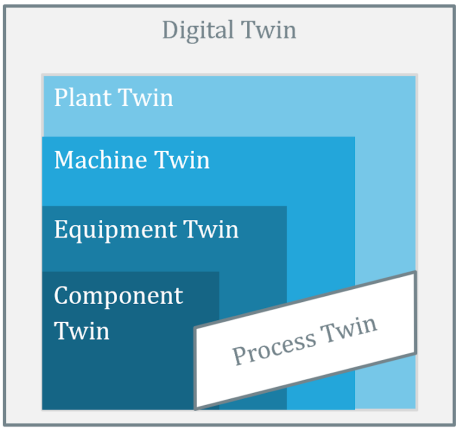


Fig. 4 DTW layers structure

### B. *Data Manipulation*

As a second step, the raw data will be processed in order to make them directly valuable for people or the upper system. This step can be called "**Augment**": basic data validation, operating mode automatic detection (off, start-up, running, max), new KPI calculated to follow performance, data manipulation (such as clusterization /filtration /linearisation) to detect abnormal operation mode, and generate an alarm in case of deviation.

To help/speed the deployment and to guarantee the consistency of the analysis, some templates will be used to define the information needed (design data, time data), the calculation (KPI, alarm..). This also allows data reconciliation and generates aggregated KPI (global reliability/efficiency of a fleet).

### C. *Share and Act*

When the information is available, some actions need to be taken to create some value. This can be done through the final part that can be called "**Share**". The operation needs to put in place an organisation in order to follow and track all the alarms. A remote center will manage the alarms generated in case of mechanical parameters moving outside of their normal clusters (to decide if it's a fake alarm, or if this is a true/serious alarm needing a stop and a maintenance to fix the detected issue). Similarly, an alarm detecting an under performance will be studied in order to understand and potentially give instructions to change the operating mode to improve the efficiency/profitability.

In front of the screen, the first level will manage the alarm generated, and if needed will escalate to a higher level with Subject Matter Expert (Maintenance expert, Rotating expert, Process Expert..).

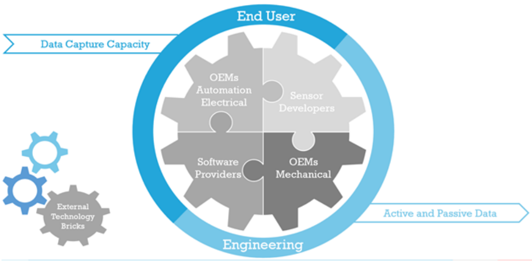

Fig. 5 Collaborative team to handle DTW

## VIII. CONCLUSION

In this article we have tried to present the best picture of DTW within the industry.
DTW is a buzz word but also a real diamond which can bring added values on each facet of the project life cycle; there is a huge number of "facets" . Usually a DTW is in fact only one or two of all those facets. The complete DTW is like a mythic diamond: nobody ever sees it, as it's today very complex and very expensive.
The term "Digital Twin" pops up more and more as companies look for ways to drive New Ways of Working and innovation, and for good reasons. Twins can help businesses monitor the state of equipment at remote sites, optimize product designs for specific needs, and even model the business itself.

## IX. REFERENCES

[1] RAMI 4.0 : Reference Architecture Model Industrie 4.0 link here
[2] CFIHOS : Capital Facilities Information HandOver Specification link here
[3] IOGP: International association of Oil and Gas Producers : link here
[4] US National Building Information Model Standard Project Committee: link here

## X. NOMENCLATURE

DTW Digital TWin
ZVEI Zentralverband Elektrotechnik- und Elektronikindustrie *(German: electrical and electronic manufacturers' association)*
CFIHOS Capital Facilities Information HandOver Specification
BIM Building Information Modeling
PID Process Instrumentation Drawing
OTS Operating Training System
MMS Maintenance Management System
AFD Approved For Design
AFC Approved For Construction

## XI. VITA

**Cécile Gaudeaux** received her Master's Degree in Electrical Engineering from Polytech'Lille in 1991 together with a postgraduate diploma in electrical engineering from the University of Lille I. She has started her career in being commissioning engineer for industrial plants with ALSTOM company. After various experiences as application engineer for protection relays and project manager, she has been lead the Air Liquide electrical department of Engineering for 2003. After being in charge of engineering and digital roadmap, she moved in January 2020 to Capital Implementation Europe entity in the technical department cecile.gaudeaux@airliquide.com

**Jean-François Rauch** graduated first from ENSIGC (1992/1995) as a Chemical Engineer with a specialization in process control/simulation, then from INSAE (Sup'Aéro 1996/1997) in a master System and Advanced Control. He spent 11 years in AL E&C in the process control department. For 12 year he's working in the AL operation support organisation, with the current position of Smart & Innovative Operation expert. jean-francois.rauch@airliquide.com

**Jean Guilhem** graduated from the engineering school Supélec Paris with a specialization in Electro-communication. After several experiences in Siemens Oil&Gas and Air Liquide Large Industry working on digital topics, he received a MBA degree from the SDA Bocconi in Milan. Joining 2b1st Consulting in 2018, he is now Operations Director.

guilhemjean@2b1stconsulting.com