

Chapter 4

A Platform for Product-Service Design and Manufacturing Intelligence



Maurizio Petrucciani, Lorenzo Marangi, Massimiliano Agosta and Marco Stevanella

Abstract Manutelligence is designed for the Product-Service business, allowing enterprises to develop innovative Product-Services, more sustainable, addressing customer needs. This platform will enable designers and engineers to access through natural 3DEXPERIENCE to data from both the “traditional” enterprise IT systems (CAD, CAX, PLM, MES, etc.) and IoT enabled systems for physical products information and knowledge management during its whole life cycle phases. The activities carried out by Manutelligence will improve the product and service development by connecting them together through cross disciplinary feedback loops by means of modular collaborative secure ICT manufacturing intelligence. The four software pillars of the Manutelligence platform are the 3DEXPERIENCE, by Dassault Systèmes, I-Like, by Holonix, MaGA, by SUPSI, LCPA, by Balance.

4.1 P-S Collaborative Design and Manufacturing Platform

Manutelligence aims at supporting the emerging trend of the Product-Service business, allowing enterprises to develop **innovative and more sustainable Product-Services, addressing customer needs**. Some of these services can be provided only after timely and accurate analysis of customers’ product usage in order to acquire useful information for new product improvements or services provision. Often the misalignment between product and service development processes and inability of concurrent engineering between both processes arise due to the lack of information exchange among the product and service life cycle phases. This generates longer time to market for the product and service, misalignment between the product and service life cycle phases, lack of sharing knowledge and product and services not adapted to the business environment/customers’ needs. Manutelligence aims to integrate best in class methodologies and tools from research and industry, resulting in a secure, cross disciplinary collaborative Product-Service Design and Manufacturing Engineering

M. Petrucciani (✉) · L. Marangi · M. Agosta · M. Stevanella
Dassault Systemes Italia Srl, Via dell’Innovazione, 3, 20126 Milan, Italy
e-mail: Maurizio.Petrucciani@3ds.com

Platform. This platform should enable designers and engineers to access through **natural 3D experiences** to data from both the “**traditional**” **enterprise IT systems** (CAD, CAX, PLM, MES, etc.) and **IoT enabled systems** for physical products information and knowledge management during its whole life cycle phases. The activities carried out by **Manutelligence** will **improve the product and service** development by **connecting them together** through cross disciplinary feedback loops by means of **modular collaborative secure ICT manufacturing intelligence**.

Therefore the innovative point is reached providing a lifecycle transversal infrastructure, able to provide to the different involved stakeholders (designers, engineers, manufacturing managers, testing, maintenance users and service team) a coherent, secure and content driven access to information (Fig. 4.1).

Moreover Life Cycle Cost (LCC) and Life Cycle Analysis (LCA) are usually a long and difficult process and cannot be directly used during the design phase by engineers, but needs specialized analysts due to the difficulty of retrieving data and defining the boundaries of the analysis. Objective of Manutelligence is to support the interaction between the engineering and the environmental (LCA) or business (LCC) analysts as well as to provide tools and methods to enable iterative calculation and optimization of these aspects.

4.2 Product Service Solution for Industrial Scenarios

The Manutelligence Platform has been developed based on industrial use cases and scenari, with the target to be applicable in the related industrial sectors.

The Manutelligence Platform design was organized to support the industrial cases of the Manutelligence project provided by the partners *Ferrari*, *Meyer*, *FabLab (Fundacio CIM)* and *Lindbäcks*. Chapter 6, about Use cases applications, is showing the use case details.

The *Ferrari* case has been developed using the CAD design and simulation capabilities for the frequency and modal analysis as well as the IoT functionalities to capture and elaborate the driver usage of the car, recording information via telemetry. The *Meyer* case has been managed implementing the enterprise change management process; this process can be triggered directly via the IoT, automatically creating the issue object containing the data coming from problems captured during the ship operations. The *FabLab* made usage of the CAD design and BOM management



Fig. 4.1 Lifecycle phases

functionalities to develop the lamp and the MOVEO (robot arm) 3d-printing case, predicting the environmental impact with sustainability tools and measuring the in operations energy consumption via the IoT solution. The *Lindbäcks* case leveraged the IoT functionalities to monitor in real time an apartment usage via a remote device, like a smartphone.

The CAD capabilities either for design or for visualization are used in *Ferrari*, *Meyer* and *FabLab* cases. The simulation capabilities are used in the *Ferrari* case for the frequency and modal analysis.

The Manutelligence Platform includes tools for the process design and manufacturing execution. These tools are intrinsically integrated with the design phase and can leverage on the IoT information coming from the operations.

The features of the platform can be applied in many different industrial cases, improving the manufacturing efficiency and quality, addressing the needs captured from the products usage by the end users.

Based on the result obtained, it appears that the Manutelligence exploitation can be extended not only to the companies of the same industrial sector, meaning automotive, shipbuilding, construction, but also to other industries where the service component can be a source of new business, like, for example, the white goods sector. In fact anywhere there is the need to gather information about the usage of the products to improve design and manufacturing there is an opportunity to adopt a solution like Manutelligence platform.

4.3 P-S Collaborative Design and Manufacturing Platform Components

The Manutelligence Platform is the result from the integration of following Partner's tools (Table 4.1):

Table 4.1 Different tools composing the Manutelligence Platform

Partner tool name	Brief description of component	Provided by partner
3DEXPERIENCE	Managing the product service design and manufacturing processes	Dassault Systemes
I-Like	Managing the Internet of Things (IoT) data gathering and elaboration	Holonix
MaGA	Managing the environmental impact analysis	SUPSI
LCPA	Managing the product service life cycle cost analysis	BALANCE

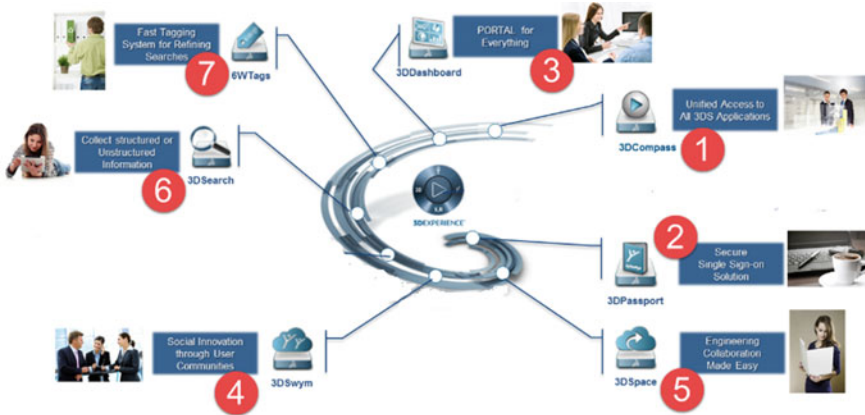


Fig. 4.2 3DEXPERIENCE's components

4.3.1 3DEXPERIENCE

3DEXPERIENCE is a Business Platform that includes Product Lifecycle Management and provides support for Business Process applications. These applications contain pre-defined schema and processes to support many business industrial sectors (Fig. 4.2).

Industry processes and solutions leverage following 3DEXPERIENCE services:

3DCompass

It's the “key to the 3DEXPERIENCE Platform”

- The compass manages access to the applications in the **3DEXPERIENCE**
- Each user has a personalized view and access to his/her licensed applications based on their selected Roles;
- Each quadrant of the compass opens a specific category of applications:
 - West: 3D Modelling (CATIA, SolidWorks).
 - South: Content and Simulation (SIMULIA, DELMIA).
 - East: Information Intelligence (3DDashboard).
 - North: Social and Collaboration apps (ENOVIA, 3DSwym).¹

3DPassport

3DPassport provides a secure single sign-on environment for the entire 3DEXPERIENCE Platform. It is based on the industry standard CAS (Centralized Authentication Service—open standard for authentication management server). In particular 3DPassport is implemented on top of CAS Server version 3.5.2.

¹CATIA, SolidWorks, SIMULIA, DELMIA, ENOVIA are Dassault Systemes brands.

3DDashboard

With 3DDashboard, user can create their own dashboard for rapid, intuitive visualization of business and product data. 3DDashboard helps managers to ask the right questions and connect the dots in the Platform. Also, the dashboard can be used for *Social Media Listening* where widgets are automatically created for a specific topic.

3DSwym

3DSwym can create social communities to collaborate in an unstructured environment. Communities contain Web 2.0 collaboration tools such as Blogs, Wikis, iQuestions.

3DSpace

It's the “core” of the 3DEXPERIENCE Platform, used to manage and share content (data, documents and related information) for effective collaboration.

The main functionalities used in the Manutelligence project are:

- *Product Planning Programs*: to improve project management execution with flexible calendars, interactive Gantt edition and to monitor the project execution with new summary view and standardized reports. These functionalities are used, in particular, to monitoring the Manutelligence project itself.
- *Global Product Development*: engineering collaboration with Product Structure/EBOM integrated experience (Lifecycle and Configuration) and improve end-to-end change governance from requirements to engineering. Managing requirements traceability versus test executions and prototypes As-Built BOM. The *Ferrari*, *Meyer* and *FabLab* industrial cases have been developed based on these functionalities (Fig. 4.3).

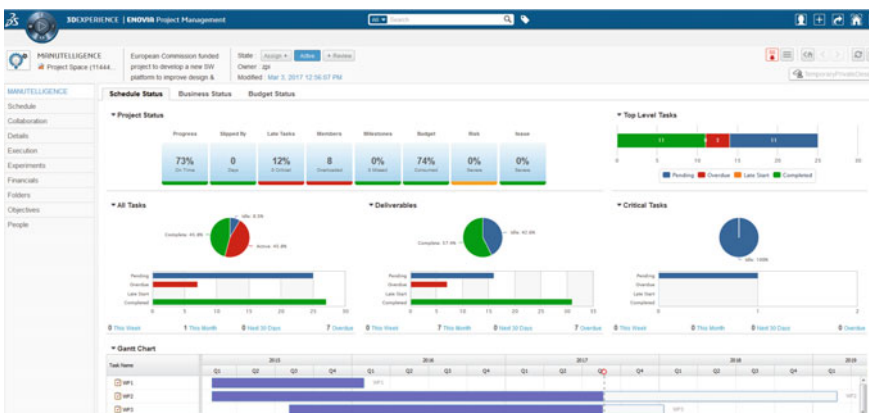


Fig. 4.3 Dashboard of Manutelligence project inside 3DEXPERIENCE

The 3DEXPERIENCE Platform Architecture is a three-tier architecture in which the presentation, the application processing and the data management are logically separate processes. The Architecture is a web based one, using the https protocol, to ensure secure data management. Access to the application can be done via web browser (Webtop Client) or via specific client application (Native Client), as shown in the following Fig. 4.4.

4.3.2 I-like

I-Like is the Holonix web platform supporting the Internet of Things (IoT) processes in the Manutelligence platform.

I-Like Architecture

The Holonix I-Like is a web platform aimed at retrieving, organizing and visualizing all the data that are relevant to know the history and the current status of a machine or product. This is the module inside the platform whose objective is to acquire data from the field. Once the data are acquired, they can be used for different analysis and with different purposes. For example, inside the Manutelligence Platform, data coming from different “sources” like Ferrari FXX high performance race car, FabLab 3D printers, Lindbäck’s wooden houses and Meyer ships are captured by Holonix I-Like. The core of the solution consists of a cloud platform, a set of gateways to read data from the field and a set of web and mobile apps to present the data to the users. Following Fig. 4.5 offers a general graphical representation of the Holonix I-Like architecture.

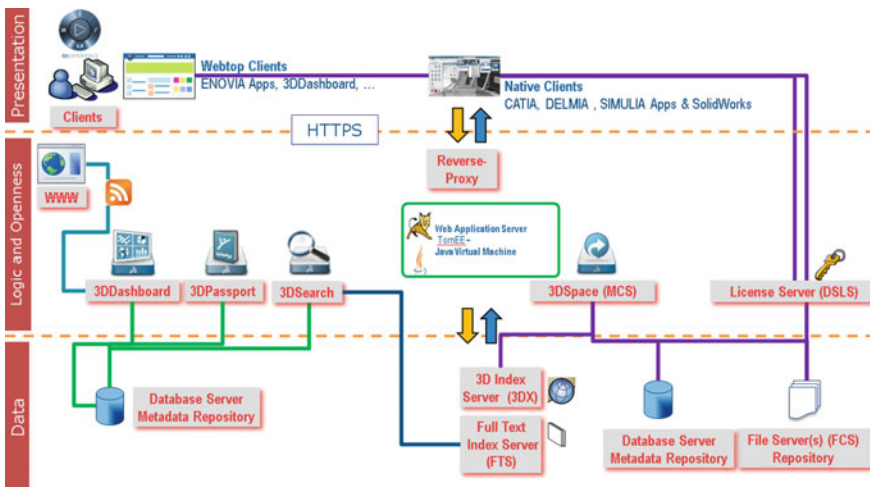


Fig. 4.4 Three-tier architecture

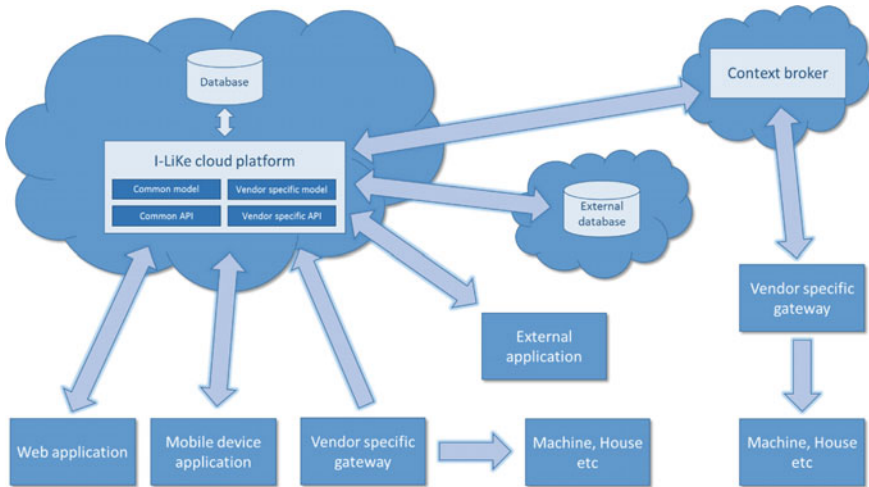


Fig. 4.5 *I-Like* architectural overview

The cloud platform is in charge of the following four main tasks:

- Storing of the relevant information collected during the machine or product life-cycle,
- Maintaining a complete representation, at any moment, of the machine or product current status,
- Keeping track of the machine or product status history,
- Detecting machines or product alarms and anomalous conditions and notify the users and maintainers about them.

To feed the cloud platform, data must be collected from the field. This is achieved by implementing a soft-ware component (gateway) that talks to the machine or product, does the basic computations that are easy to be performed with low latency access to the machine and sends the data in a secure way to the cloud platform adhering to its API. This part is often customized to the specific case, as protocols might change across various machines types and might be proprietary. It can reside on hardware already present on the machines or on embedded systems added on purpose. A Representational State Transfer (REST) API allows exchanging information with third-party applications while the Application framework is used to interconnect together many modules providing security aspects, relations and logics with the stored data.

4.3.3 *MaGA*

MaGA is a software for Life Cycle Assessment developed by SUPSI. It was developed as a standalone application. In the Manutelligence context it is integrated as an application of the platform.

The Life Cycle Assessment calculation is based on the availability of a Bill of Material (BOM) of the Product to be analyzed.

The Manutelligence Platform is designed in order to let *MaGA* import the BOM from 3DEXPERIENCE Platform. Anyway *MaGA* can be used standalone and the BOM can be created from scratch using the *MaGA* UI.

A specific interface was developed so that the user can, during the *MaGA* session, import the BOM automatically and add all the information needed for the environmental impact calculation.

The *MaGA* session data can be saved into the 3DEXPERIENCE Platform, so that the calculation can be carried out and refined by different users on different workstation as needed by the work organization.

Once the Assessment calculations are completed, the final results can be uploaded in 3DEXPERIENCE Platform, making it available to all the users, as per the access rules implemented.

4.3.4 *LCPA*

LCPA is a software for Life Cycle Costing developed by Balance. It was developed as a standalone application. In the Manutelligence context it is integrated as an application of the platform.

As in the case of *MaGA*, the Assessment calculation is based on the availability of a Bill of Material (BOM) of the Product to be analyzed, and for that reason the Manutelligence Platform was designed to let *LCPA* import the BOM from 3DEXPERIENCE Platform. Anyway *LCPA* can be used standalone and the BOM can be created from scratch using the *LCPA* UI.

A specific interface was developed so that the user can, during the *LCPA* session, import in the BOM automatically and add all the information needed for the environmental impact calculation.

Once the calculations are completed, the final result can be uploaded in 3DEXPERIENCE Platform, making it available to all the users.

Table 4.2 Data exchange

Involved systems	Technology used	Exchange format data
MaGA ← → 3DEXPERIENCE	REST web service	JSON/XML format
LCPA ← → 3DEXPERIENCE	REST web service	JSON/XML format
I-Like ← → 3DEXPERIENCE	REST web service	JSON format
I-Like ← → LCPA	REST web service	JSON format

4.4 P-S Collaborative Design and Manufacturing Platform Integration

Data exchange between four components of Manutelligence Platform (3DEXPERIENCE, I-Like, MaGA, LCPA) is ensured through the use of Web Services technology that provide a standard means of interoperating between different software applications, running on a variety of platforms and/or frameworks.² The following table shows technology end exchange formats adopted (Table 4.2).

The workflow of the data exchange between 3DEXPERIENCE and MaGA as well as 3DEXPERIENCE and LCPA can be summarized in the following steps:

- Retrieve list of existing products from 3DEXPERIENCE to MaGA or LCPA.
- Retrieve the BOM (Bill of Material) for a specific product from 3DEXPERIENCE and import it into MaGA or LCPA tool.
- Perform the Assessment with MaGA or LCPA tool.
- Send the Assessment from MaGA or LCPA tool to 3DEXPERIENCE to make it available for the platform users collaboration.

This solution will allow an iterative process to converge to the optimization of the environmental impact as well as on the life cycle costing since the early stages of the Product-Service design. In fact this workflow can be applied immediately, driving the materials selection, the design solution and taking into account the whole life cycle of the product, including the service and the disposal phases.

The workflows of the data exchange between 3DEXPERIENCE and I-Like can be summarized in the following steps.

Meyer Case

- The “Meyer management system”, hosted by Holonix, is retrieving, organising and visualising all the data that are relevant in order to know the history and the current status of a specific Boat.
- When an anomalous condition occurs, the on board system launches the alert to the operator for the local action and transmits the information about anomalous condition to the 3DEXPERIENCE Platform creating automatically an Issue.
- The Issue can be the start point for the Change Management process.

²<https://www.w3.org/TR/ws-arch/>.

Ferrari Case

- The telemetry system, hosted by Ferrari plus Holonix (steering wheel accelerometer), is retrieving data measured during the specific trip of a specific car; the I-Like user can organize and visualizing such data.
- The organized data will be automatically transferred to the 3DEXPERIENCE to allow the structural analysis, in particular the frequency and modal analysis to improve the drive style performance by introducing the appropriate powertrain transmission changes to avoid resonance and vibration amplitude. The data transferred will be classified and identified by 3DEXPERIENCE, providing to I-Like a unique identifier of the specific trip session.

Lindbäcks apartment Life Cycle Costing Case

The workflow of the data exchange between *I-Like* and *LCPA* can be summarized into the following steps.

- I-Like gets and stores data coming from Lindbäcks apartment (e.g. temperature, alarm, humidity).
- LCPA automatically downloads from I-Like the averages measured values of the sensors for a given interval; the energy consumption will be calculated in LCPA.
- The real energy consumption, based on measurements in the apartment, and the energy costs, based on actual price models, are calculated.
- LCPA tool compares the “real” energy consumption of the apartment based on measurements with the calculated energy consumption based on mathematical models.

In this way the apartment designer is able to compare theoretical calculation with measured data and then can improve the energy consumption due to optimized isolations for the next apartment.

The apartment tenant is aware of his energy consumption and the energy consumption costs on a daily basis and also room-related (in case the measurements are done in every room) and he is enabled to adapt his energy consumption habits based on real measured data.

4.5 P-S Process Design and Manufacturing Execution Tools: 3D Modeling (CATIA and Solidworks)

The goal of the activity of the Design Engineer is to create and document the process required to develop new objects from the concept phase, up to the engineering phase. All the business processes are implemented by CATIA and Solidworks modules, in the framework of Dassault’s *3DEXPERIENCE* platform.

4.5.1 Product Structure

The Product Structure is the product representation of the way it is conceived, developed and engineered. This is the basis to develop the Bill of Materials and to execute simulations to validate the product.

In the context of CATIA module the basic objects to design are:

- Physical Product, used for the assemblies (the “branches” of the product tree).
- Physical 3D Part, used for the component (the “leaves” of the product tree).
- Representations.
- 3DShape, containing the 3D geometry.
- Drawing, containing the 2D geometry.

These object are used to create the Product Structure (also know as product tree) and to create the 3D geometry, enabling the visualization experience of the products (Fig. 4.6).

4.6 3D Modeling

The design of a product can start from scratch by creating a sketch or re-using library objects or via carry-over of previous products to modify to design new ones. There is a bunch of functionalities available to capture the intent of the designer in order to facilitate and speed up the product development, as well as tool to control the data access and the product maturity follow-up in a quality context.

The results that can be obtained are the ones developed for the Manutelligence industrial use cases (Fig. 4.7).

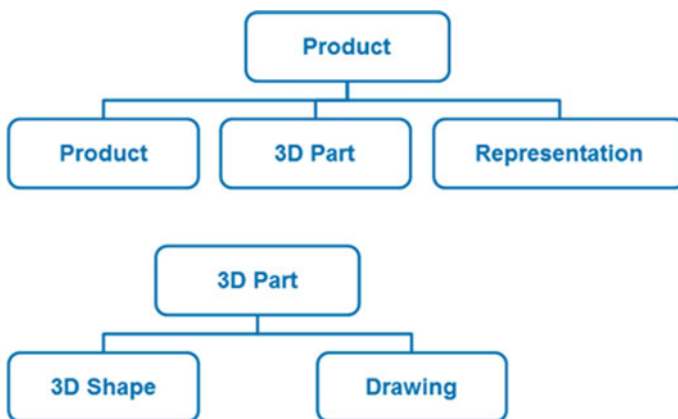


Fig. 4.6 Product’s structure

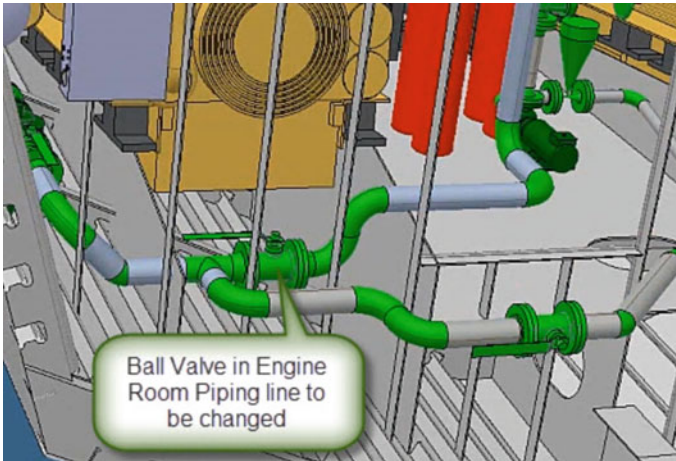


Fig. 4.7 Ship example

Similar result can be obtained using the Solidworks module, part of the 3DEXPERIENCE Platform, as done by Fundacio CIM for the FabLab case of the lamp.

4.6.1 Visualization

The visualization is supported by the 3DEXPERIENCE and by the Manutelligence Platform, leveraging on the CATIA and Solidworks features.

In particular, the visualization is useful when applied to the sessions of Digital Mock Up (DMU) usually adopted for design reviews, where designers and product managers analyze the progress of product development for approval milestones.

Typical features offered by the DMU are:

- The analysis of entire assembly, filtering as needed to check the desired parts or systems.
- The clash analysis on a configured scenario, i.e. by selecting one of the possible configurations of the product, e.g. a car with right or left driving seat.
- The visualization for consulting is available with web applications that do not require specific CAD capabilities.

As example for the FabLab case, the 3D visualization is available navigating the Bill of Materials in the web browser, offering view and annotation tools (Fig. 4.8).

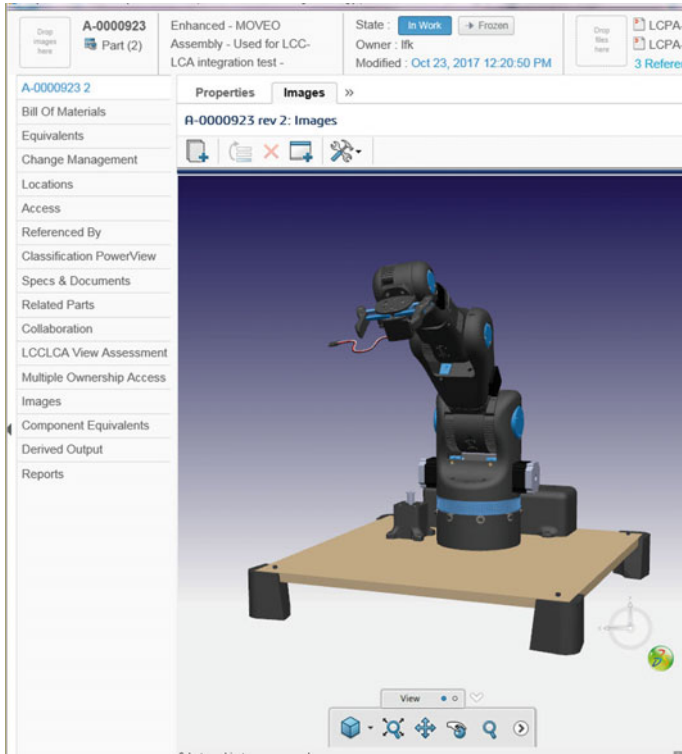


Fig. 4.8 Visualization of the Moveo (FabLab case)

4.6.2 Simulation Modeling (SIMULIA)

The 3DEXPERIENCE Platform extends traditional product lifecycle management (PLM) concepts to simulation, by offering a single platform for managing CAD and simulation data and processes, thus permitting seamless design iteration based on simulation results. The Manutelligence Platform is extending these capabilities by directly being fed with real data captured during product usage thanks to the IoT solution (Holonix).

The goal of the activity of the Simulation Analyst Engineer is to simulate with virtual tools the behavior of the objects being developed by the Design Engineers to validate and document the process and to develop new objects from the concept phase up to the engineering phase. All the business processes illustrated are implemented in the Physics Modeling apps, based on the SIMULIA technology, within the framework of Dassault's 3DEXPERIENCE Platform.

Simulation data in the 3DEXPERIENCE Platform are organized into three major categories: Model, Scenario and Results.

Model

The Model contains the data required to perform a finite element simulation of the product. In particular, the Model contains a finite element model representation (FEM Rep) that is a representation of a model, always associated with either a 3D Part or a Physical product, in which the geometry is discretized into many geometrically simple elements (mesh) according to the finite element method.

A FEM Rep can be associated with a simulation object thereby allowing multiple simulations to be associated with the assembly. These FEM Reps can contain different meshes and associated properties.

The 3D Part or Product mesh can be created using several different algorithms. In particular, the mesh of the 3D volume can be obtained by using tetrahedral or hexahedral elements with different levels of refinement; in the same way, the 3D surface mesh can use either triangular or quadrilateral elements. The model, in addition to the mesh elements, can include connector elements that simulate the physical connections of relative movement and degrees of stiffness values/damping, imitating the behavior between the parts of the model (Fig. 4.9).

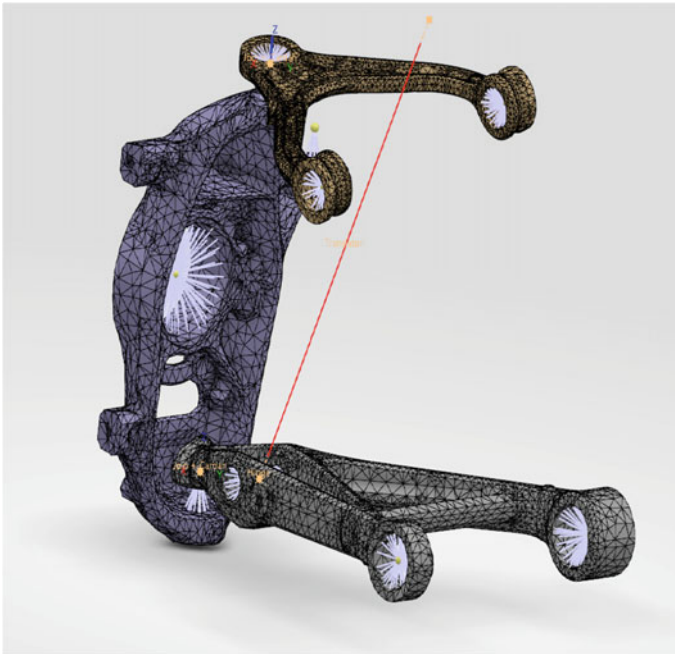


Fig. 4.9 Finite element model using tetrahedral elements. In red color, connector elements schematizing a shock absorber

Scenario

The Scenario consists of different objects that describe how a simulation is performed; the availability of certain types of actions will depend on the type of scenario creation app.

In the Scenario, the type of analysis procedure to be performed is specified; this can be a general static analysis, a non-linear implicit or explicit dynamic analysis, or a linear dynamic analysis. Within each steps, the relevant external loads (e.g. gravity, pressure, concentrated forces) and restraints are applied to the model, together with output requests for the analysis.

In particular, in the Scenario the link between the CAD data and the Internet of Things data occurs. For example, considering the Ferrari use case, telemetric data coming from the test drive and processed by Holonix are imported onto the Manutelligence Platform in tabular format (e.g. CSV format) and used to create (amplitudes of the forces in time/shift) the applied loads and/or displacement as boundary conditions (Fig. 4.10).

Once the Simulation Scenario has been completely defined, it is possible to execute the analysis by specifying the number of cores to use to leverage the scalability of the SIMULIA solver.

Results

Results, in the context of simulation, contain the outcome of the executed analysis, including output variables, reports and animations that can be viewed in the Physics Results Explorer app.

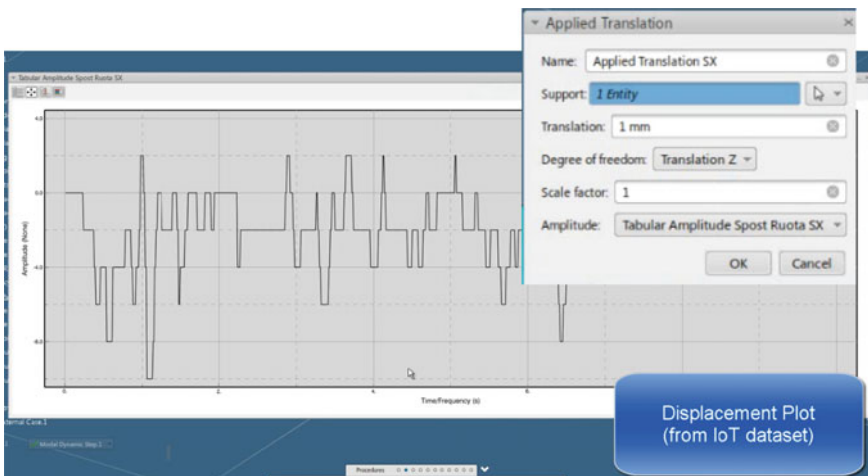


Fig. 4.10 Input from telemetry



Fig. 4.11 Comparing simulation results versus measured data

The Physics Results Explorer app enables results visualization from applications relevant to both designers and experts. In addition, it enables collaboration between multiple users and integration with design optimization. Physics Results Explorer uses parallel processing to take advantage of high-performance, multi-core systems and enables to process the results of large realistic finite element simulations.

Regarding Ferrari use case, two analysis steps were performed. In the first step, the resonance frequencies of the structure were extracted; in the second step, the dynamic behavior of the model was evaluated. Then, results were post-processed in terms of resonance frequencies and corresponding deformation modes in the first step, while in the second step the dynamic forces/displacements acting on the system were plotted.

Moreover, history plots are available as X–Y curves; in this way, time-dependent quantities calculated during the numerical analysis and physical quantities available thanks to the IoT integration, are easily comparable within the Manutelligence Platform (Fig. 4.11).

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits any noncommercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if you modified the licensed material. You do not have permission under this license to share adapted material derived from this chapter or parts of it.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

