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**(I) DIGITAL TWINS AND INDUSTRY 4.0: VIDEOGAMERS WILL STAFF AND
MANAGE INDUSTRIAL PROJECTS IN THE NEAR FUTURE**

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Using smart objects based on existing international standards and imbedded physics allows the creation of complex systems with the ease of playing with LEGO. The objective is complete simulations of industrial plants, just like airplane cockpit simulators. One may create rich and immersive Collaborative Work Environments (CWE) for complex projects by combining Big Data data bases hosted in the Cloud, Block Chain secured, rendered using the same methods as videogames, communicating in real time including the data from IoT devices and biometric avatars of the workers.

It represents a whole new and better way to design, build, operate and maintain refineries, buildings, airplanes and trains, as all the information of the project is maintained in a Digital Twin of the real asset, and all its history is accumulated in a Digital Thread or Project Lifecycle Management. Machine Learning and Artificial Intelligence will lead to complex industrial plants learning how to operate safely and with greater efficiency.

Keywords: digital twin; digital thread; PLM; IoT; IIoT; immersive environments

**(I) GEMELOS DIGITALES E INDUSTRIA 4.0: LOS VIDEOJUGADORES DE
HOY SERÁN LOS TRABAJADORES QUE GESTIONARÁN LAS
PLANTAS INDUSTRIALES DE MAÑANA**

El uso de objetos inteligentes basados en estándares internacionales existentes y física integrada permite la creación de sistemas complejos con la facilidad de jugar con LEGO. El objetivo es simulaciones completas de plantas industriales, igual que los simuladores de cabina de avión. Se pueden crear entornos de trabajo colaborativos (CWE) ricos e inmersivos para proyectos complejos mediante la combinación de bases de datos Big Data alojadas en la nube, securizadas con Blockchain, y renderizadas utilizando los mismos métodos que los videojuegos, comunicándose en tiempo real, incluidos los datos de dispositivos IoT y avatares biométricos de los trabajadores. Representa una forma completamente nueva y mejorada de diseñar, construir, operar y mantener refinarias, edificios, aviones y trenes, ya que toda la información del proyecto se mantiene en un Gemelo Digital del activo real, y toda su historia se acumula en una Bitácora Digital o Gestor Integral del Ciclo de Vida del proyecto. El Machine Learning y la inteligencia artificial llevarán a que plantas industriales complejas “aprendan” ellas mismas a operar de manera segura y con mayor eficiencia.

Palabras clave: gemelo digital; digital thread; PLM; IoT; IIoT; entornos inmersivos

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1. The Challenge

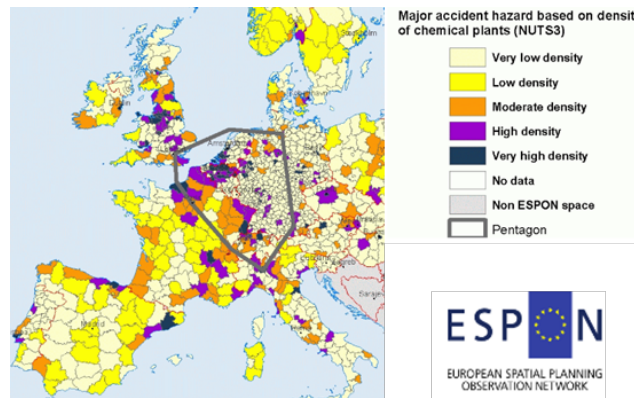
Industrial companies operating complex facilities face serious challenges in Maintenance and Operation (M&O), which represent more than 80% of the Total Cost of Ownership (TCO)¹. Applying the 4th Industrial Revolution technologies (Industry 4.0) as presented in this paper, result in an estimated 30% cost savings^{2 3 4 5}, and over decades of operation, add up to more than the entire design and construction of the plant. These savings come from monitoring and exploiting accurate, real time data, for improved safety, higher efficiency, and predictive maintenance. Instead of waiting for something to break, sensors throughout the plant provide data that is analysed to anticipate problems. Unplanned downtime costs 10X initial budget due to the disruption and lost production⁶. This may also avoid a catastrophic failure or environmental disaster. The Top 6 challenges are:

- 1) Poor Asset Management: The overwhelming volume of industrial assets makes it impossible for companies to control their individualized performance and effective management in real time^{7 8};
- 2) Deficient Security Management: Geographical dispersion and remote locations of many facilities, diverse processes and incompatible data formats make it difficult to establish and maintain cybersecurity;
- 3) Disconnected Data Silos: Processes are stored on multiple different spreadsheets and documents using isolated software or asset management tools for and duplicated by individuals, creating the potential for unidentified errors, lack of compatibility between departments and loss of value across the enterprise. Technical documentation often lacks logs or lose traceability, is paper-based, and not readily available;
- 4) Incompatible and Proprietary Data Formats: A veritable industrial Tower of Babel, as companies in the same industry have not agreed on data sharing standards and are subject to version upgrades and incompatible proprietary formats among software vendors, which results in the lack of a comprehensive, integrated view.
- 5) Rapid Obsolescence of Technological Platforms means that industrial plants, with life cycles between 30 and 50 years, lack permanent solutions based on data formats meant for long-term M&O.
- 6) Difficult Coordination and Execution of Complex Tasks: Teams struggle to work effectively as:
 - Tasks are difficult to describe without visual aids;
 - Repair manuals and maintenance records are unavailable;
 - Travel is costly when experts are needed at remote locations;

- Communication breaks down from central to remote offices;
- Inadequate teleconferencing resources at remote plant locations make remote assistance difficult and frustrating.

Managing assets using “*wait until it breaks*” maintenance methods puts operations at risk—physically and financially—represents a continuous threat to the lives of thousands living nearby as shown in the Chemical Plants Hazard map (Fig. 1) and costs the global economy billions every year. Many plants are old, pushed beyond their original capacity, which present serious challenges regarding their safe activity and should be modernized. TALENT SWARM® offers a unique and immersive Collaborative Work Environment (CWE) that updates and optimizes the overall asset operational safety and efficient performance using Digital Twin Simulators.

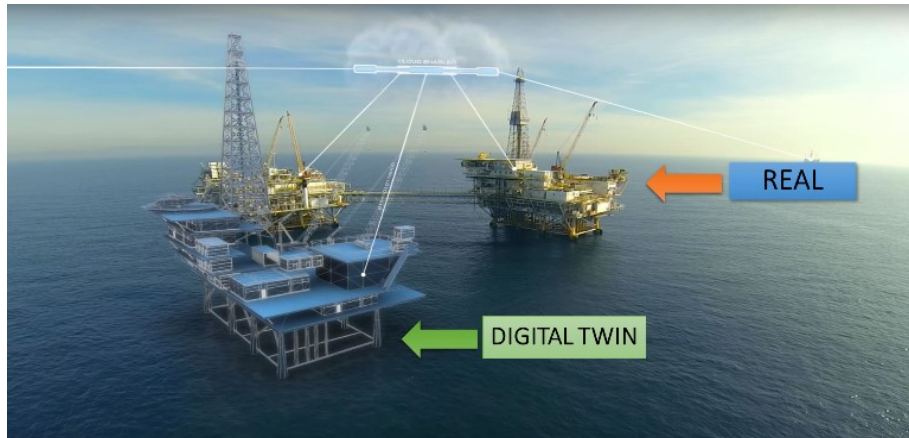
Figure 1: Chemical Plants hazard map in UE



WHAT IS A DIGITAL TWIN SIMULATOR?

A virtual model of an industrial plant, object or process that uses Internet of Things (Industry 4.0) sensors to provide real time data integrating software analytics and Artificial Intelligence. The data collected is used to create a ‘twin’ connected to the physical world, to show real time operation and accumulate historical information, to better operate, simulate, and predict how the plant, object or process will respond under real and test conditions (Fig. 2).

Figure 2: Digital Twin Simulator of an offshore petrochemical platform



2. THE SOLUTION

We offer a solution for owners of complex industrial assets such as industrial plants, refineries, water treatment facilities to easily create their Digital Twin Simulator⁹ like the immersive Second Life¹⁰ and SimCity¹¹ videogames, but to do real work.

A Digital Twin Simulator is comprised of thousands of Smart Objects, like a 3D virtual LEGO®, each part reproduced visually and mimicking the actual behaviour of the physical system using mathematical simulation algorithms and Artificial Intelligence (AI). This allows operators to monitor and increase efficiency, anticipate failures and avoid unexpected shutdowns for the entire plant's lifecycle.

The people who operate and manage those assets also have their own digital version, a biometrically accurate avatar, to interact and work remotely with other persons and industrial assets from any place at any time with Virtual Reality (VR) and Augmented Reality (AR) with collaborative intelligence, hence the project's name.

We believe that COLLABORATIVE WORK ENVIRONMENTS (CWE) where real workers and industrial assets work together with their avatars and digital twin simulators are the future scenario that will enable the next level of Project Lifecycle Management (PLM) to boost productivity and profitability of industrial businesses by saving an expected 30% of the costs in Maintenance and Operation (M&O).

TALENT SWARM (TS) is an Open Data Format, Block-Chain secured, Cloud-based Platform-as-a-Service (PaaS) that offers a unique and immersive Collaborative Work Environment (CWE) that optimizes the overall asset and operational performance FOR asset-intensive companies in the world (environmental, petrochemical, industrial and energy), who manage and operate valuable and complex industrial assets with highly qualified teams of people around the globe, often in remote locations with currently deficient asset information.

Talent Swarm displays the entire industrial plant as a Digital Twin Simulator, once the platform is loaded with the necessary information. It is the digital copy of the physical plant, the equivalent of a virtual meeting place for authorized persons from a company's entire global network of employees and external experts to congregate and discuss Maintenance & Operation (M&O). Examples range from remediating an incident, analysing the history of a piece and foreseeing its future behaviour, searching for a replacement and requesting pricing, organizing an augmented reality M&O training session and much more. Adding real-time data coming from sensors in the actual plant, the platform runs mathematical simulation and artificial intelligence analytics for users to understand how every component and processes operate for greater safety and efficiency.

Figure 3: Talent Swarm Platform and industrial applications



Contrary to the practices of existing market solutions that emphasize non-interoperable software standards, Talent Swarm's core is based on an information data repository using the non-proprietary, open information handover specification standard CFIHOS to insure the

long-life of the stored data. Once the industrial plant information is connected using this standard, internal and third-party software applications easily share the secure data repository to offer advanced services to clients during the plant's several decades of expected life. To achieve these goals, Talent Swarm intends to connect as many of the most desirable and breakthrough technologies as a "Platform of Platforms" and create a true synergistic Collaborative Working Environment.

WHAT IS CFIHOS?

CFIHOS which stands for Capital Facilities Information Handover Specification is an accepted industry standard for a consistent approach to information handover and beyond, based on the ISO 15926. It provides: 1) A common standard for all information needed to operate, maintain and decommission a facility; 2) Simple interoperability among users and systems; 3) Non-proprietary, open standard for long-term data storage and reuse for repairs and revampings. SHELL, SIEMENS and HEXAGON are some of the many CFIHOS compliant companies (Fig. 4).

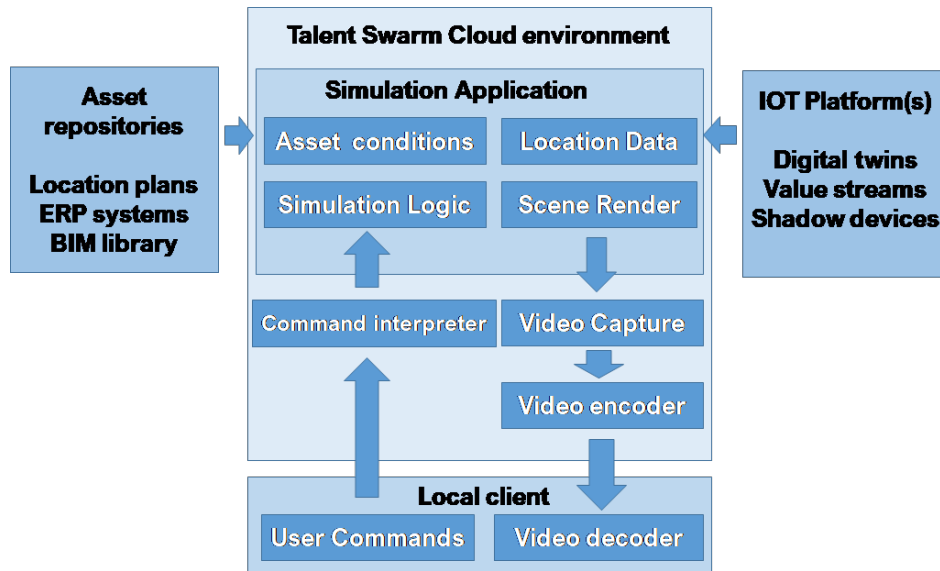
Figure 4: CFIHOS participants as of 29 May 2018



3. CONCEPT AND METHODOLOGY

Talent Swarm provides a Cloud Platform as a Service (PaaS) with all the necessary functions to store models ("Digital Twin Simulators") of industrial facilities for real-time monitoring and advanced simulations with a modular industrial object structure that clients may configure on a functional "block by block" basis (Fig. 5).

Figure 5: Talent Swarm PaaS functional technology map



Its disruptive innovation applied to industry is the application of 3D videogame rendering to create immersive Collaborative Work Environments (CWEs) to do real work among local and remotely connected workers. At a basic level, after scanning the plant with lasers, together with existing CAD drawings, it allows a Virtual Tour of the plant to accurately visualize and manage operations and repairs.

It is based on the Open (Non-Proprietary) CFIHOS standard specification for industrial information, Blockchain-secured, and Cloud-based to optimize operational and maintenance performance for global asset-intensive companies (energy, petrochemical, industrial, environmental and manufacturing), that manage and operate valuable and complex plants with highly qualified teams of people around the world, often in remote locations.

Talent Swarm provides rich, real-time information through a Digital Twin Simulator a dynamic software model of the corresponding physical asset, in which technical personnel represented by biometrically-accurate and Blockchain-secured Digital Avatars interact, in appearance similar to a videogame, but performing real work. Telepresence solutions provide remote guidance of multiple technical personnel from a central location.

The heart of the Talent Swarm platform is a constantly updated data repository stored in the Cloud based on the open standard CFIHOS. The entire lifecycle records are maintained for decades (from initial design, construction, and assembly, to plant handover, operation and maintenance, and dismantling), secured with Blockchain technology, to provide an operation log and audit trail avoiding unauthorized access. Each individual piece of critical equipment is tracked, and all its relevant information is stored and connected from the SCADA control system or PLC and IoT devices, and real-time conditions may be “tagged” and queried. With links to the Computerized Maintenance Management System (CMMS) established, technicians may click on the pieces of equipment to retrieve maintenance manuals and repair work orders. These “recommendations” for better Maintenance & Operations performance allow workers to virtually walk around the plant, and have a narrative character, as in *“The pump XYZ appears to be unstable, the probability that it will break down in the next two days is 85%. We recommend creating a work order for further inspection.”* As software capabilities evolve, the data repository provides a reliable historical archive of operation called a Digital Thread, further improving plant efficiency and design with ongoing advances in Artificial Intelligence and Machine Learning.

The Methodology to build a plant Digital Twin Simulator is based on successively adding the following levels of increasing complexity that improve the synchronicity between the model and its physical plant (Fig. 6):

Figure 6: Synchronicity between Model & Physical plant with increasing complexity



Level 1. Geometry. Web-based Virtual Tour Application, integrated with scanned Point Clouds, Wi-Fi Mesh integration to be installed for geolocation of operators/Avatars, later using 5G Internet.

Level 2. Smart Objects and Full Project Lifecycle Open Data Archive. Connection to BIMobject, a repository of industrial part catalogues, new VR/AR hardware integration and an advanced graphics rendering engine. Extension of the Equipment Inventory Data Connection to include technical specification sheets, maintenance information, suppliers, equipment, drawings and part lists, prices and geolocation within the plant. Data base will be a CFIHOS-compliant long-term open data storage. Dashboards to be user configurable to view data.

Level 3. Plug & Play IIoT platforms and maintenance solutions using Real-time data. Seamlessly connect Talent Swarm to TeleControlNet-IIoT and Thinger.io-IoT platforms so the SCADA and Industrial IoT sensor information is tied to its corresponding equipment in real-time. Integration with Abismo, a Computerized Maintenance Management System (CMMS) to enable preventive and prescriptive maintenance.

Level 4. Include Avatars and remote collaboration tools. Remote Immersion improvement for collaborative work with AR, VR, and biometric Avatars for virtual tour navigation in the Digital Twin Simulator with minimum bandwidth requirements and compelling game design fundamentals.

Level 5. Run simulation and predictive maintenance and operation through machine learning and mathematical models. Integration of mathematical simulation capabilities for M&O enhancement using Modelica and Advanced Program Interfaces (APIs) to connect to a variety of Artificial Intelligence (AI) and Machine Learning (ML) services, i.e. Semantum. Integration with current and additional temperature, vibration and harmonics sensors for continuous Electric Motor Monitoring, Data Analysis and Prescriptive Maintenance algorithms.

4. ADDRESSING INDUSTRIAL USER NEEDS

Talent Swarm addresses the needs of medium to large asset-intensive industrial companies, as well as process engineering contractors that manage and/or operate valuable and complex industrial assets with highly qualified teams of people located globally and especially those with employees in remote locations. The target users of the Talent Swarm platform are engineers, technicians and managers who work both in industrial plants and at the companies' headquarters, with design, planning, control, management, operation and maintenance tasks. Talent Swarm Introduces a major shift in the way plants are managed, allowing the contractor or designer to monitor the plant performance and introduce operating improvements.

The main needs the Talent Swarm platform solves are summarized in 3 S's: **Safety, Savings and Sharing.**

1. **Safety** comes from the optimum maintenance of the industrial plant and constant real-time monitoring to detect potential failures and prevent unscheduled shutdowns and possible catastrophic events.
2. **Savings** in operating costs come from 3 main areas:
 - Avoiding costly and time-consuming development projects of customized asset management software that are in separate data silos and not integrated. The standardised CFIHOS common data repository allows Plug & Play connection of existing multiple industry platforms and expert systems in a fast and scalable way. Cost savings are realised by increasing the predictive capabilities of the Digital Twin Simulator that collects more operational data (i.e. vibration analysis, energy efficiency, advanced monitoring, collaborative tools, etc.).
 - Reducing unexpected plant shutdowns and the breakdowns by the connection with maintenance programs to provide predictive and later prescriptive maintenance or simulation models fed by IIoT data that help to understand plant functioning to improve operational efficiency, simulate extension or replacement of plant components, etc. AI/deep learning libraries will play a prominent role in predictive maintenance activities.
 - Collaborative intelligence for problem solving using real-time information, mathematical simulations or AR/VR to directly connect global experts for remotely-assisted repairs, training and future robotic interaction.
3. **Sharing.** Talent Swarm addresses the costly need for expert engineers to travel to far-flung locations. Talent Swarm "gives engineers the ability to work anyplace, anywhere, anytime, from any device." Local technicians may be assisted remotely by experts at the headquarters that can "see" in the Digital Twin Simulator exactly what is at the plant. The local technician may then solve a complex issue, while assisted by the remote expert.

While the exact figure varies by industry, Maintenance and Operation (M&O) at Industrial companies represents 80% of Total Cost of Ownership (TCO) and unplanned downtime costs a business 10X the cost of planned maintenance due to business disruption and lost production, estimated to be a full 1.5% of sales revenue. We believe target users be willing to pay for the benefit of reduced downtime as Talent Swarm provides real-time tracking & monitoring of physical assets, which helps in anticipating and diagnosing equipment faults. The following benefits are based on Talent Swarm's shift from passive reactive to anticipatory prognosis in M&O:

We have determined the interest of future customers as well as that of future technological partners and investors. These include an industrial association (AEQT) with some of the major industrial actors in Europe, such as CEPSA, REPSOL and SHELL. We also have the

support of the Nuclear Energy Industry (ANAV). We have the support of 2 large industrial companies that have already tested an initial version of Talent Swarm: RAVAGO Plastics (Belgium), and SACYR AGUA (Spain). A variety of software companies are on board that add value to Talent Swarm with optional enhancements such as Big Data analytics, Artificial Intelligence and Machine Learning. We also have the investor interest from NEXXUS.

Furthermore, we believe plant operators will find a lucrative ROI given the following Key Performance indicators:

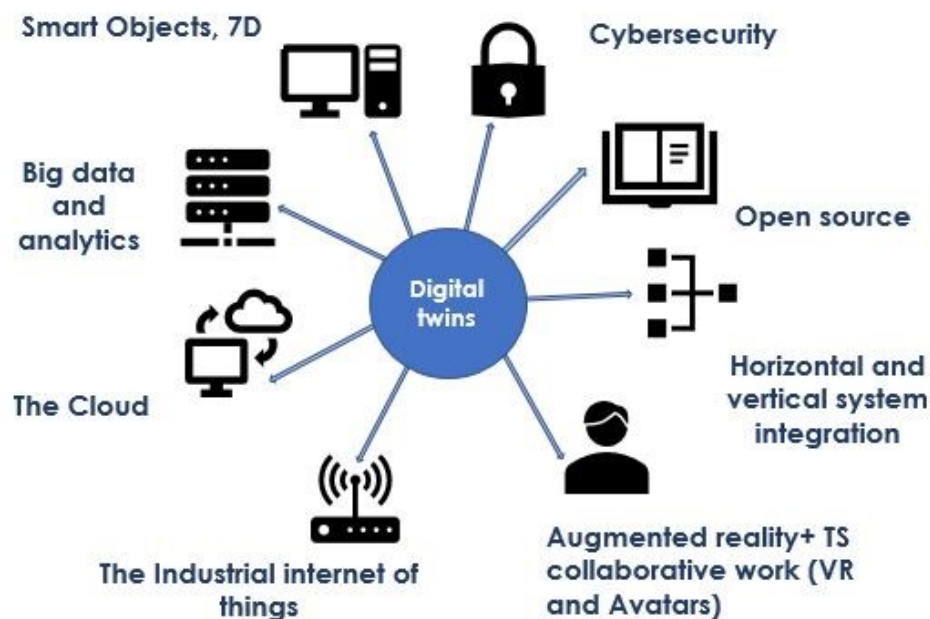
- Reduction in Total Cost of Ownership (TOC) 5-30%,
- Life-time extension of the targeted large machinery and plants by at least 20%;
- Increased availability 2-6%,
- Reduction in reactive maintenance 10-40%,
- EH&S incident reduction 3-40%,
- Gain in employment productivity 5-25%

5. UNIQUENESS OF TALENT SWARM'S INNOVATION

Talent Swarm's key innovation is both its strength and greatest opportunity: the creation of a fully explorable Digital Twin Simulator, linked to Project Lifecycle Management (PLM) and other platforms. The all-in-one expandable, modular system caters to business needs for efficiency and security inherent in a Digital Twin Simulator, protecting industrial information with Blockchain technology secured traceability, and the global oversight and collaboration benefits of a system designed from the start to enable remote-working, videogame-trained workforces of the future and learning through simulation and analysis (Fig. 7).

Figure 7: Interaction between Talent Swarm Digital Twin and Industry 4.0 technology

INTERACTION BETWEEN DIGITAL TWIN AND THE MAIN INDUSTRY 4.0 TECHNOLOGY IN TALENT SWARM



- Adopts CFIHOS at the heart of its data repository, a shared, open and non-proprietary standard that is rapidly becoming the preferred method for documenting interoperable industrial objects and systems.
- Targets environmental industries and has already developed key agreements with recycling plants, water and industrial waste treatment and desalination plants.
- Reduces CO₂ footprint by reducing unnecessary travel, a benefit increasingly sought by corporations scrutinized by customers, as well as cost-efficient functioning of current industrial infrastructures.

The advance in the state of the art offered by Talent Swarm is its integrative approach and remote operation capabilities that consider the whole industrial plant unlike other solutions that only consider separate equipment. For the first time, Talent Swarm brings the creation of an integral 3D virtual model to provide simulation scenarios and biometrically accurate Avatars of the personnel to build an immersive Collaborative Working Environment. Talent Swarm differs from the proprietary solutions proposed by software giants in the use of CFIHOS' Open Standard that allows the platform data to belong to the customer and freedom to operate with the data. In addition, it allows the easy addition and connection with advanced industrial platforms and expert systems including advanced data analytics, machine learning and Modelica's mathematical simulation.

SUMMARY

Talent Swarm® provides rapid creation of realistic, digital replica simulators of industrial facilities connected to their physical twin to operate and maintain them with greater safety and increased efficiency. In an immersive collaborative visual environment based on open, non-proprietary international data standards it provides a long-term secure data repository for Project Lifecycle Management (PLM), and connects with Industry 4.0 maintenance, operations and Artificial Intelligence & Machine Learning from other providers.

As a Hollywood pitch, Talent Swarm is “*SimCity for Industrial Plants, but Saving Lives and doing Real Work*”. Welcome to the Industry 4.0 Renaissance!

Figure 8: Early Proof of Concept prototype of Talent Swarm Immersive Digital Twin Simulator



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