Hiroshi Toriya
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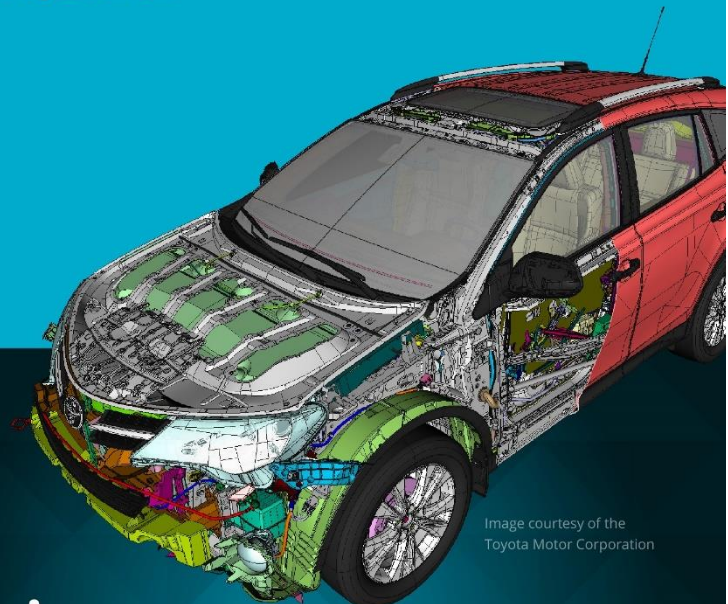

Image courtesy of the
Toyota Motor Corporation

Using 3D Data to Improve Manufacturing Processes

How Manufacturers are Leveraging their 3D CAD Data to Lower Costs, Improve Quality and Accelerate Time-to-Market

Image courtesy of the Toyota Motor Corporation

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Notes:

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A special thank you to Toyota Motor Corporation for providing the cover and other images used in this book. Also, thank you to the other companies who provided images, in order of appearance: Taiho Seiki, Tsubamex, and Niigita Power Systems.

Hiroshi Toriya is founder and CEO of Lattice Technology, Inc. and creator of XVL — an ultra-lightweight data format for 3D geometry and a container for authored information such as work instructions and PMI.

Foreword

This book was first published in Japan with the title "Strategy to Utilize 3D Technology in the Manufacturing Industry." The original focus was how Japanese manufacturers could use lightweight 3D technology – specifically XVL – to optimize their production processes and better compete in the global marketplace.

However, the benefits of lightweight 3D are not limited to Japan. Countries around the world are developing their manufacturing bases. The US is a good example of this, where there is a renewed push for domestic production. Faced with relatively high labor costs, US manufacturers must find ways to maximize productivity to compete in the global marketplace. One way to do that is to leverage the value of their 3D design assets.

Global manufacturers are using 3D CAD and developing huge troves of 3D CAD data. Lightweight 3D technology such as XVL enables them to utilize those assets to drive efficiencies not just in design and production, but throughout the organization to lower costs, improve quality, and enhance customer satisfaction.

I hope that you enjoy this book and that you find its examples useful as you consider how to unlock the potential of your 3D design assets.

Marc Jablonski
San Francisco, California

Introduction

The global manufacturing sector is evolving rapidly. Recently the U.S. government has made efforts to strengthen the manufacturing industry and promote "reshoring" of domestic manufacturing operations that had moved overseas.

At the same time, US companies are striving to increase productivity by making manufacturing smarter. They are applying IT in the form of the Internet of Things (IoT), which enables devices to communicate with each other to optimize production. This "Industrial Internet" concept was championed by GE and is now being spearheaded by the Industrial Internet Consortium, which was founded by GE and other US manufacturers.

Following these efforts, Germany launched a government-led high-tech Industrie 4.0 strategy, the "fourth industrial revolution." Then modelled on this scheme, China unveiled its "Made in China 2025" initiative, a 10-year plan aiming to become a "manufacturing and production world power." Japan has followed suit with its "Industrial Value Chain Initiative" in 2015. In this way, a "major industrial revolution" is currently taking place in industrial powers around the world led by joint efforts in the public and private sectors.

The globalization of manufacturing has accelerated collaboration between countries and regions with different languages and cultures. This often results in language or cultural barriers. 3D models can help overcome these barriers. Using 3D models to communicate ideas reduces the need for text translations and fosters understanding across languages and cultures. Such communication goes both ways – 3D models give remote production teams the ability to provide clear feedback to the design departments, enabling manufacturers to enhance quality in upstream processes. This means that IT can accelerate global optimizations.

Now let's consider another benefit of IT: "virtual vs. reality." The progress of IT technologies has enabled the verification of 3D engineering data without the need for engineers to see or touch the actual production machines. In the future, IT devices such as sensors and networks will report the status of the manufacturing plant in real time and combine this information with virtual models of the plant to verify the data. This book aims to introduce state-of-the-art technologies for data verification methods using virtual models, along with some case studies of these methods, and their prospects.

So, amidst the current manufacturing revolution, what must a global manufacturer do to win in the competition with its rivals around the world? One answer is to leverage 3D design data to optimize the global production process, from design and development to production, sales, and service.

However, there is a problem – the large size of 3D CAD data has made it very difficult to use outside the design environment. For instance, even today is it is difficult to display the full 3D model of a single vehicle on a PC. Moreover, it is almost impossible to send 3D data to places with poor network connectivity.

The result is that even though the design departments of global manufacturers have largely adopted 3D CAD, the 3D models that they produce are not being used adequately. The full application of design assets such as CAD data throughout the company is extremely important for global collaboration. It is essential to change such design assets to the asset of the "whole company."

The solution to this problem is "XVL," a unique 3D application infrastructure technology developed by Lattice Technology, a company that I founded in 1997. This book will introduce XVL and show how leading manufacturers such as Toyota, Casio, Brother, and Hitachi Construction Machinery are using it to revolutionize their design and production processes.

For a manufacturer to succeed in the global marketplace, it needs to use IT innovations such as XVL to develop optimized processes and implement these processes as standards throughout the organization.

I hope that this book will serve as an opportunity for as many companies as possible to use 3D data – their design asset – to succeed in the global marketplace.

In writing this book, I had valuable discussions with the top management of manufacturing companies and managers promoting the use of IT at these companies. I would especially like to express my heartfelt appreciation to Toyota's Eiji Hikosaka, Brother's Shinji Suzumura, Tsuneishi Shipbuilding's Takuma Ashida, Hitachi Construction Machinery's Kiyohiko Otani, Casio's Hideo Kashiwakuma, Niigata Power System's Kazuhiko Fukuoka, Mitsubishi Mandra's Masashi Kawamoto, Tsubamex's Yoshiyuki Arai, TSK's Hideki Takeda and Kazuo Sakada. Finally, I would like to thank all the staff at Lattice Technology such as Akemi Fukuhara and Riko Ito for their support, as well as everyone at Gentosha.

Hiroshi Toriya
Tokyo, Japan

Chapter 1: Global Manufacturing Renaissance

The World is Undergoing a Manufacturing Renaissance.

Major changes are taking place worldwide in how companies produce manufactured goods. Leading manufacturers need to take these changes into account to remain competitive in the global environment.

Not long ago, the 21st century was anticipated to usher in a “financial age” in which the financial industry would eclipse manufacturing as the key industry. However, the financial crisis of 2008 changed the economic trend lines. Now, led by the U.S. and Germany, movements to revive manufacturing have gained strength across the globe.

Since 2008, the U.S. government has been proactively implementing policies to revive the manufacturing industry. Also, there are robust private sector efforts led by companies such as GE to evolve manufacturing technologies using IT. At the same time, Germany has launched “Industrie 4.0” aiming to strengthen their domestic manufacturing industry.

What challenges and opportunities to these trends present to global manufacturers? Before getting into that, let’s look at the current situation of the competition for dominance in manufacturing between the U.S. and Germany.

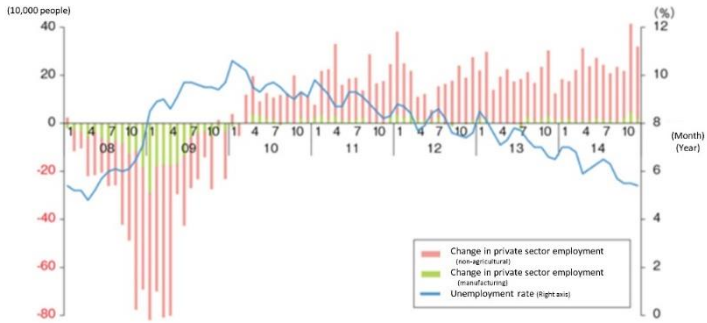
U.S. Government Efforts in America’s Manufacturing Renaissance

Over the past few years, the U.S. government has made strong efforts to support the manufacturing industry. In his State of the Union Address in 2012, President Obama said that “this is a great opportunity to revive manufacturing in the U.S.”. In another State of the Union Address in 2013, he said that the “middle class is the true driving force of economic growth in the U.S., and rebuilding this class will help revive the prosperity of the U.S.” and pointed to efforts to increase employment in the manufacturing industry to support and rebuild the middle class.

To rebuild the manufacturing sector, the U.S. government has particularly focused on “reshoring” — returning manufacturing jobs to America. To bring back companies which have moved manufacturing overseas seeking inexpensive labor, the U.S. government has adopted various policies that provide benefits and support for domestic production. For instance, in 2014, the government launched a policy to promote innovation in the technological development of new materials, advanced sensor technologies, and digital manufacturing, foster manufacturing talent to apply these technologies effectively, and support the use of new technologies by small and medium sized companies.

Helped by other favorable trends such low crude oil prices due to the shale gas revolution and soaring labor costs in emerging nations, these efforts are presently bearing fruit. In the two years between January 2013 and December 2014, the number of employees in the manufacturing industry increased by 34,000 people, with the unemployment rate dropping to 5.4% at the end of 2014 and recovering to the same level as before the financial crisis. Exports by American companies have also been increasing continuously for four years since 2010, reaching a record high of 2.3 trillion dollars in 2013.

Figure 1-1: US Employment Count and Unemployment Rate 2008-2014



Note: "Change in private sector employment" is the difference from the previous month (Number of private sector employees in the present month subtracted from that in the previous month)

Data: U.S. Bureau of Labor Statistics

Source: Ministry of Economy, Trade and Industry website "2015 Manufacturing White Paper".

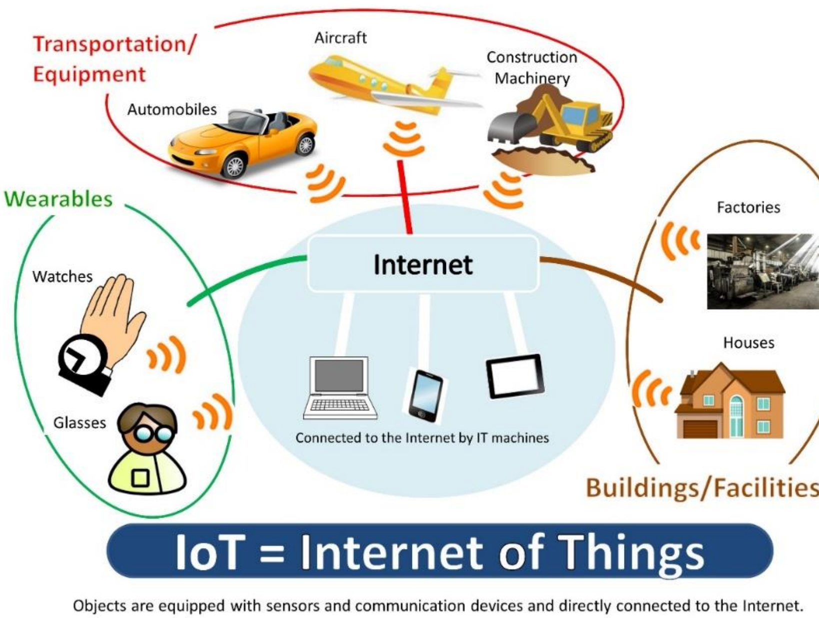
Manufacturing Innovation in America Led by Private Sector

In addition to the public sector, private sector efforts are driving U.S. manufacturing innovation U.S. manufacturers are enthusiastically adopting cutting edge technologies such as 3D printers, big data, and IoT.

The Internet of Things, or IoT, is the concept of a network of connected devices other than PCs and servers. For instance, by wearing a body mounted electronic device, even people can be connected to networks. Objects can be connected to the network by equipping them with sensors and communication functions. Since the data can be imported directly from the sensors, objects in remote areas can also be controlled.

Some companies are already using IoT effectively. For instance, copy machine manufacturers are remotely monitoring and detecting errors in their machines, and proactively dispatching service providers to visit the customer and make the necessary repairs. In addition to remote monitoring, they are coming up other novel ways of applying IoT such as providing individualized instructions and warnings during regular inspections, recommending the best combinations of toners and paper per the state of the copy machine, and even automatically determining when to replace the machines. By providing remote access to an object's state, IoT is treasure box of information for developing new business models and manufacturing service processes.

Figure 1-2: What is IoT?



GE Promoting the Industrial Internet

Manufacturing giant GE is promoting IoT as the "Industrial Internet." Previously GE had been focusing on long-term financial business as the central pillar of its business, but in recent years, the company is aggressively moving away from finance and returning to manufacturing. In April 2015, they announced plans to sell their real estate business and related financial assets worth about US$26.5 billion and downsized their financial business to under 10% by 2018.

As part of their "return" to the manufacturing industry, the company is focusing tremendous efforts on IoT. The company is combining IoT with big data to create exciting new development processes and business models. Specifically, they are already collecting operational data from various products equipped with sensors and using this data for analyzing product maintenance and operations, and for the development of new products and services.

For instance, at GE turbine test facilities for power generation, 5,000 sensors are attached to a turbine to obtain information on temperature, air pressure, vibration, etc. The information is then analyzed by specialists to improve combustion efficiency. IoT has enabled the company to obtain massive amounts of data in a very short period of time, allowing them to gain insights quickly and sharply reduce development time and costs.

GE calls this business strategy the "Industrial Internet" and explains its significance as follows.

> "The real opportunity for change...surpassing the magnitude of the consumer internet...is the Industrial Internet, an open, global network that connects people, data, and machines."
> **-- Jeff Immelt, GE Chairman & CEO**

Industrial Internet Consortium

In 2014, five leading American companies including GE, Intel, and IBM came together to found the "Industrial Internet Consortium" to standardize best practices and accelerate the growth of the Industrial Internet. In this way, in the U.S., IoT defaults are being established and standardization being initiated, led by the private sector.

Germany Launches Industrie 4.0

At the same time, Germany launched its government-led strategy to promote the computerization of the manufacturing industry "Industrie 4.0.", meaning the "fourth industrial revolution." The concept was first introduced in the 2011 Hannover Messe (an annual international trade show held in Hannover).

Industrie 4.0 references the latest industrial revolution following the past three:

1) Mechanization of production using water and steam power
2) Mass production using power
3) Automation of production processes using electronics and IT

Industrie 4.0's purpose is to merge cyber space and the actual world with computers to create new values, development and manufacturing processes, and business models with the aim to achieve further advancement of manufacturing.

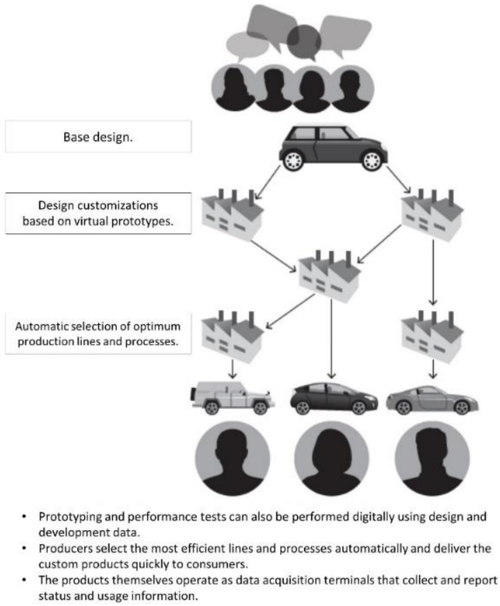
Smart Factories and Mass Customization

Industrie 4.0 aims to apply cutting edge technologies such as IoT to promote smart factories and mass customization.

Smart factories are intelligent factories that can “think.” Production facility information and sensor data are collected and analyzed in the cloud and used to implement optimum production management and quality control. In theory, all production machines could operate autonomously and produce an optimal production process. Taking this to the next level, it should be possible to connect individual smart factories so that an entire region can function as a massive smart factory.

Mass customization is producing individually-specified products at the same costs as mass-produced products. For instance, providing cars in unique colors and designs at prices near those of standard cars. By linking information on market needs to smart factories, the Industrie 4.0 strategy is pursuing the ultimate mass customization.

Figure 1-3: Mass Customization



Industrie 4.0 Echoes Toyota’s Production System

It can be said that Industrie 4.0 aims to standardize Toyota’s famous Kanban system, the just-in-time inventory management approach that manufactures "only what is needed when it is needed, and in the amount needed." With this method, information such as the number of parts required to manufacture the products are written on signs put up at the manufacturing plant and the manufacturing staff will go to the pre-process to obtain the required parts when manufacturing the products. Industrie 4.0 is attempting to digitize these steps and implement the process by exchanging information over the Internet, which has the potential to extend the system beyond the factory walls to include suppliers and customers.

Toyota’s Kanban system also focuses on “autonomation” whereby a machine will stop when a defect occurs. “Autonomation” is an example of automating the supervisory functions, not just the production functions. The result is that the factory staff does not have to monitor the machines, greatly reducing costs. The use of IoT will enable smart “autonomation” through automatic detection of failures throughout the entire manufacturing process. In short, Industrie 4.0 can be seen as an attempt to leverage IoT to eliminate human factors and optimize control of the manufacturing process.

Platform Industrie 4.0

In April 2013, a group of German governmental, academic and industrial organizations founded a strategy planning committee called Platform Industrie 4.0. The committee has specified the following priority development areas.

1) Standardization and structuring of information network
2) Construction of foundation of structural system
3) Establishment of broadband infrastructure
4) Development of standard network security technology
5) Development of labor skills and work style in the digital industry age
6) Specialized education and sharing of success experiences
7) Creation of legal frameworks for data protection.
8) Enhancement of efficiency such as energy consumption.

Three main strategies can be seen here: establishing infrastructures led by the government, deciding social rules, and educating workers so that they can adapt to the new environment.

Industrie 4.0 aims to realize the goals by 2025.

Platform Industrie 4.0 vs. Industrial Internet Consortium

While initially seen as competitive, in 2016 the Industrial Internet Consortium and Platform Industrie 4.0 announced an agreement to cooperate to ensure compatibility between their efforts going forward. This is expected to reduce potential barriers and speed the standardization and adoption of IoT technology.

Made in China 2025

Inspired in part by Germany's Industrie 4.0, China has launched the "Made in China 2025" (MiC2025) initiative - a 10-year plan aiming to become a "manufacturing and production world power" by 2025. The goal is to upgrade China's manufacturing industry, with an emphasis on the following sectors:

1) New advanced information technology
2) Automated machine tools & robotics
3) Aerospace and aeronautical equipment
4) Maritime equipment and high-tech shipping
5) Modern rail transport equipment
6) New-energy vehicles and equipment
7) Power equipment
8) Agricultural equipment
9) New materials
10) Biopharma and advanced medical products.

Like Industrie 4.0, MiC2025 attempts to apply advanced technologies like IoT, big data and cloud computing to manufacturing. With MiC2025 China aims to move up the manufacturing value chain and compete at a higher level with other top manufacturing powers such as the U.S., Germany, and Japan by 2025. China's goal is to become the undisputed top manufacturing country in the world in 2049, the year marking its 100th anniversary of the founding of modern China.

Germany and China

German manufacturers see Industrie 4.0 as more than a roadmap for technology innovation. One Siemen's executive called Industrie 4.0 an international strategy for manufacturing. Illustrating this point is the fact that Germany and China have agreed to collaborate and to promote Industrie 4.0.

In 2015 at CeBIT – Europe's largest IT tradeshow – in Hannover Germany, German Chancellor Merkel said: "collaboration between Germany and China will promote the Internet of Things of the manufacturing industry." In response, Chinese Premier Li Keqiang promised cooperation in a video speech saying "China also wants to spread Industrie 4.0".

Also, SAP of Germany and Foxconn – China's largest exporter -- announced plans to strengthen technological development ties, indicating deepening private sector alliances between Germany and China.

Adapting to Global Trends

With increasing global alliances and industrial standardization, manufacturing competition is becoming even more intense. What measures will ensure success in such an environment? Eventually, standards will develop, and manufacturers need to be prepared to comply. The most crucial thing now for manufacturers to do is to construct reliable development and production processes capable of supporting next generation manufacturing tools and business models.

Chapter 2: Winning in the Global Market

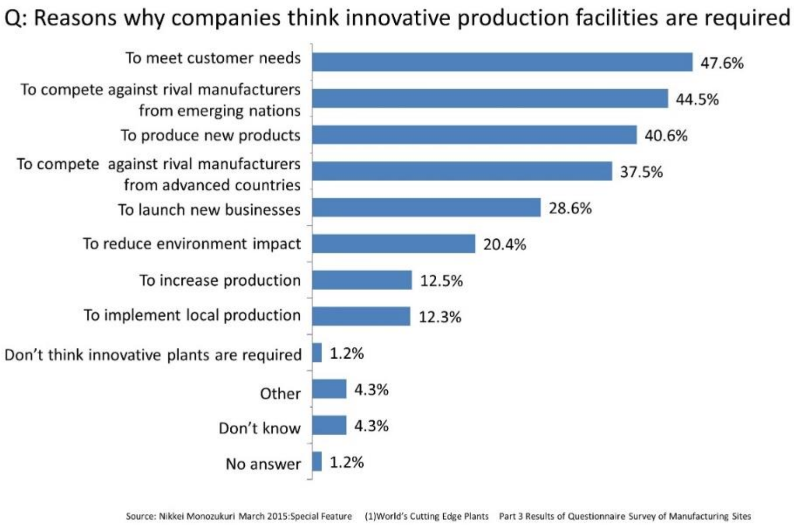
Challenges of Global Production

In today's global production environment, the question of where to locate manufacturing functions such as design and production facilities is crucial. In the past, manufacturers generally located their flagship plants, which showcase their production technologies, in their home countries, and from there expanded their technologies to overseas plants.

However, this led to key personnel and technologies gradually moving abroad so that facilities at overseas plants became more sophisticated than those at home. For this reason, many manufacturers found that their domestic plants were no longer the main plants. Rebuilding or upgrading the domestic plants is an opportunity to improve manufacturing efficiency by "bringing home" the lessons learned abroad.

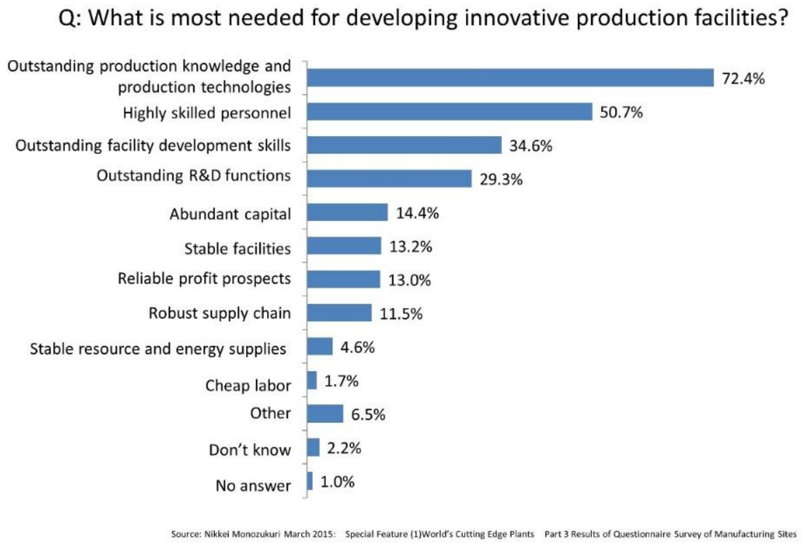
Nowhere has this issue been more apparent than Japan. In 2015 the magazine Nikkei Monozukuri surveyed manufacturers about this issue, and the results are interesting. According to the survey, 86.8% of manufacturers replied that "innovative plants" are crucial for improving competitive strength. The top three reasons for this were "to meet customer needs, to beat rival manufacturers in emerging nations, and to manufacture innovative products." In this case, "innovative plant" refers to totally new plants; not upgrades or extensions of conventional plants regarding production technologies, processing technologies, facilities, and production lines.

Figure 2-1: Innovative production facilities are required to win in the global marketplace.



Furthermore, when asked what they thought was the most needed to realize such innovative plants, the number one reply by far was "outstanding production knowhow and technologies." Manufacturers are fully aware that production technologies are a source of competitive strength to the domestic manufacturing industry, and that advancing domestic production and technological skills is critical to long-term success.

Figure 2-2: Outstanding production technologies are the key to global competitive strength.



How IT Can Contribute to Changing the Manufacturing Industry

Prof. Fujimoto of Tokyo University says that IT itself does not improve manufacturing performance. Instead, making good use of IT is far more important. In other words, companies can improve their performance by applying IT to support and enhance their manufacturing processes.

One example of this is the use of 3D CAD and PLM in product design. Many companies that moved to 3D CAD for design have improved design efficiency using interference checks, CAE, and other tools. The CAD models are maintained in PLM systems that enable sharing of product models and management of the design process.

Overall, CAD and PLM systems make it possible to design and manufacture more diverse products more quickly than before. The design data accumulates in the PLM repositories, forming assets that can be used to drive even greater performance gains downstream from design if used effectively. However, such design assets are often not used effectively.

Why? One reason is that 3D CAD is difficult to use. It is very large, making it difficult to handle the data on computers other than the high-spec systems in product design. And access to it requires expensive licenses. At the same time, PLM systems are expensive and difficult to use, making it unrealistic to give access to the whole enterprise. And finally, the product structures in the PLM system are often defined by designers and do not meet the needs of downstream users. For instance, plant staff usually want to know how to assemble the product. However, very few companies manage this information using PLM. Current PLM systems are often too expensive and slow to be able to do this.

Lightweight 3D Data Can Convert Design Assets into Company-Wide Assets

Even though we live in an era where information can serve as a global asset, design information including 3D models are not being fully used by the departments such as production engineering, prototyping, manufacturing, marketing, and service. It is not being used because it is locked away in engineering. It is locked away for the reasons mentioned earlier and one more – the 3D model size. For example, the CAD data size of a full car model containing several thousand parts can exceed 10 gigabytes. We call these giga-models, and they are commonly produced as companies design increasingly complex products. Such massive data cannot be handled by the standard PCs normally used for creating documents and sending emails in the downstream departments.

To be able to use 3D data downstream, it is necessary to reduce its size. Reducing the size of the CAD model enables the 3D data to be used by anyone for their specific needs, making the 3D model data a company-wide asset. For instance, the 3D model data can also be used to create parts catalogs, making it a service asset. In this way, lightening the 3D design data turns it from a product development asset into an asset for the whole company.

Creating and Using 3D Data of Actual Manufacturing Sites and Products

Here's another example of the benefits of lightweight 3D data. Many manufacturing plants use old facilities and buildings. In many cases, there are no paper drawings of these facilities and buildings. Even if there are drawings, they usually differ from the real thing, because such facilities are often upgraded without updating the paper drawings.

Now laser scanners can scan such sites to produce accurate 3D models of current conditions. The scanners produce point cloud data, which consists of thousands of 3D points, often with color information. The size of the point cloud data can range from tens to hundreds of gigabytes.

Given the availability of this data, it is possible to visualize and analyze the current environment along with 3D CAD models -- for example to check whether a new piece of equipment will fit in an existing facility. Again, it is almost impossible to handle such data on standard PCs. What is needed is a system that can integrate and smoothly display 3D models and point cloud data.

So what can lightweight 3D data do? Let's look at the three applications:

1) Support global production.
2) "CAD+1" for resolving problems which cannot be resolved with just CAD.
3) Enabling concurrent facility design.

Lightweight 3D for Global Production

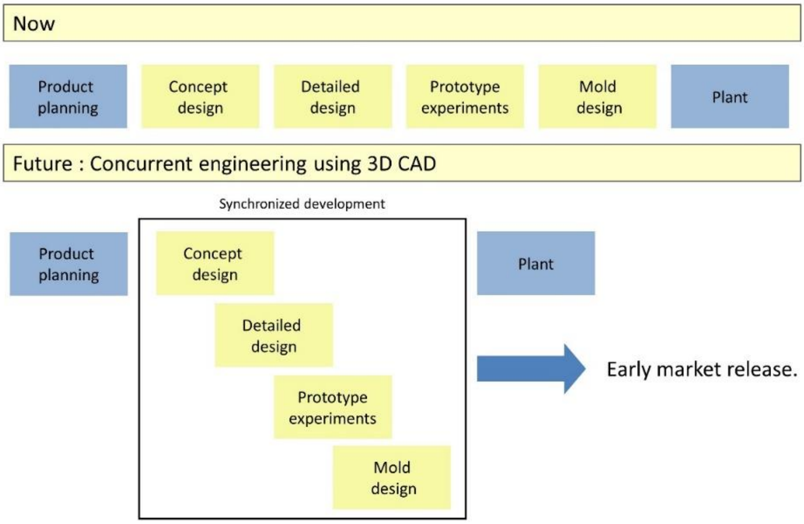
In today's global production environment, many languages are spoken on the shop floor. Also, many new workers lack manufacturing experience. It is difficult or impossible to teach assembly procedure to such new workers using just words.

One solution is to produce 3D animated assembly instructions. The goal is to overcome the barriers between cultures and languages using 3D data, providing a clear understanding of the optimal procedure. Such 3D animated instructions can be automatically created by combining lightweight 3D data with manufacturing assembly procedures.

Enhancing Production and Technological Skills with "CAD+1"

Now, let's look at production technologies. Shortening production time is key to remaining competitive. One way to shorten production time it to use concurrent engineering, a development method which aims to perform all processes from design to manufacturing in parallel using 3D CAD.

Figure 2-3: Effect of concurrent engineering using 3D CAD.



This leads to the concept of "CAD+1", which aims to add more information to mechanical CAD data. Such addition information might include electronics, mechanics or point cloud information corresponding to actual manufacturing sites or products. For instance, if there is electronics information, then the system can automatically analyze the product for short-circuits, etc. This will enable defects to be discovered and fixed in the design stage that would previously only be discovered after making the actual product and conducting experiments.

Another example is when planning installation of new equipment at a plant. Scanning the plant produces a digital model (point cloud) of the current conditions. Combining this data with the lightweight 3D model of the new equipment enables the planner to check for clearances, review installation procedures, etc. “CAD+1” thus allows the digital review of new equipment together with existing facilities even before the new equipment is completed.

Enabling Concurrent Facility Design

Finally, let’s look at the facility design process. Some manufacturers design production facilities domestically and install the facilities at their overseas manufacturing plants. Not only does this approach keep production knowledge local, but it also speeds the launch of successive overseas facilities.

However, unlike product design, the development of facilities for mass production is often carried out using conventional methods. Engineers often spend considerable time on the digital design review of mass produced products using PLM, because products are very important to the company. On the other hand, they often spend very little time on reviewing the digital data of the manufacturing facilities that are used to make the products. There are a couple of reasons for this. One is that the number of facilities is limited. Another is that the facilities are internal to the company vs. the products which go to customers. Thus, with less review facility engineers risk making endless adjustments at the manufacturing site.

The control software development department are usually the ones who suffer most from this. The operations of plant facilities are usually performed by control software because the debugging work is carried out after the actual facilities have been installed. If simple and easy to use 3D models are available, this work can be done before the actual facilities are installed, enabling concurrent facility design.

3D CAD Assets Provides Massive Value to Manufacturing Industry

If a company has massive design assets, effective use of the assets is of great value to the company. The information locked up in the design department has tremendous potential value, but only if it can be used throughout the enterprise. Not using it due to the lack of IT infrastructure is an enormous opportunity loss to the company.

Companies that can provide the design information to all the departments in the company in the form they require can maximize the value of the design assets. Manufacturing can implement concurrent engineering, where issues are found and resolved early, reducing costs, increasing quality and shortening time to market. Other departments can use to lightweight 3D data to optimize their individual processes, leading to company-wide efficiency gains.

This vision -- sharing on a global scale, enabling different departments to optimize their functions -- is a model for how IT can be a source of competitive strength for companies in the IoT age.

Chapter 3: XVL, A Fundamental Technology for Maximizing the Value of Design Assets

Why is the Use of 3D Design Spreading?

3D CAD serves as the fundamental tool for design. Used by most manufacturing companies, 3D CAD is contributing to the design and manufacturing of diverse products. So, what are the factors that have driven the popularity of 3D CAD?

Improves design quality

With 2D drawings, it is possible to design realistic, practical products. It is also possible to design something that cannot be made because the design is an abstraction in 2D. However, in the 3D world, only shapes that exist in real life can be designed.

Prevents interference problems

In product design, deciding the positions of the parts making up a product is a very important task. However, when the parts of a product are being designed by many different designers, there are inevitably interference problems. In 3D CAD, interferences can be checked automatically.

Reduces use of prototypes

With digital 3D models, analytical software can check product strength, heat dissipation, etc. This reduces the need for physical prototypes.

Improves understanding of the design

3D data can clearly show curved shapes, complicated structures, etc. which are difficult to visualize on 2D drawings. This allows those who could not understand the 2D drawings to participate in design reviews.

Supports additive manufacturing
3D data is required for building objects using 3D printers. Objects designed using 3D CAD can be prototyped using 3D printers, enabling them to be checked and reviewed. This can contribute enormously to shorter delivery times and improved quality.

In this way, 3D design offers significant benefits to the manufacturing process -- particular to design departments. Furthermore, lightweight 3D data can be distributed to the whole company, changing it from a design asset to a company-wide asset. As a result, processes in different departments can proceed concurrently, and this efficiency serves as a new source of competitive strength.

Maximizing the utilization of design assets enables quality improvements, cost reductions and shortened time to market. This chapter introduces XVL lightweight 3D technology for enabling this "ultimate concurrent engineering."

What is Ultimate Concurrent Engineering?

The goal of maximizing the value of PLM assets is to enable company-wide processes to run concurrently. The concurrent design process described in Chapter 2 was based on the use of 3D CAD design data. It can be expanded company-wide using lightweight 3D XVL technology.

XVL is software for creating lightweight 3D models from any 3D CAD application, virtually all are supported. 3D models are more useful and versatile than physical prototypes. They can be used for tests and analyses which are not possible with prototypes. Combined with manufacturing assembly data, they can be used to validate assembly processes and produce 3D animated assembly instructions. Given a 3D scan of a factory floor, the models can be used to determine if a new production tool will fit. By adding procurement information, they can be used to generate parts catalogs. The uses of lightweight and accurate 3D data can reach throughout the enterprise to external stakeholders and even to customers.

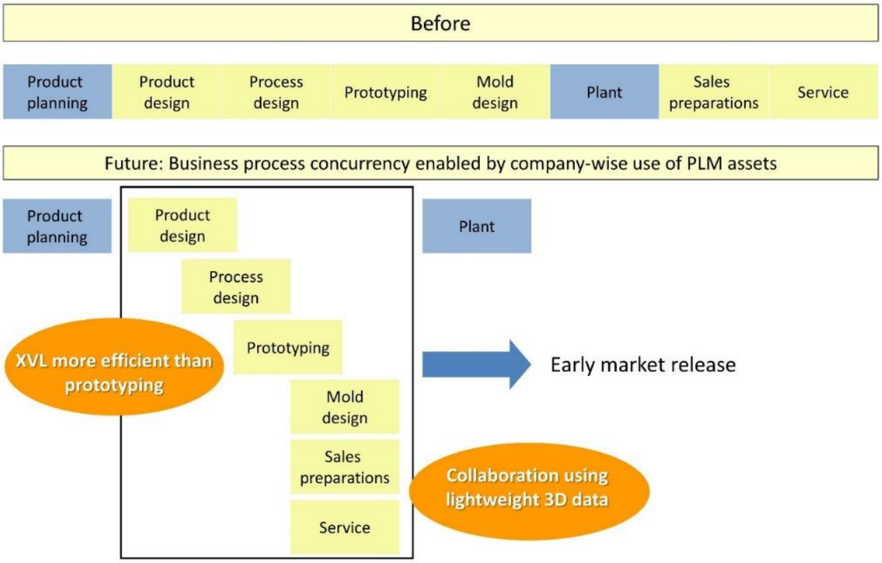
The figure below illustrates the "ultimate concurrent engineering" enabled by the XVL concept. Whereas the current engineering concept in chapter 2 was limited to the design department, ultimate concurrent engineering extends throughout the enterprise.

Recently, more and more service and marketing preparation departments are encouraging the concurrency of activities. They are performing verifications and work from an early stage using XVL models instead of prototypes and participating in global collaboration using lightweight 3D data.

Toyota calls concurrent engineering "simultaneous engineering." Simultaneous, because ideally, all manufacturing processes should proceed simultaneously. This is exactly the world that XVL enables.

XVL Resolves the Bottlenecks Faced in the Use of CAD Assets.

Figure 3-1: Business process concurrency using XVL technology



What is XVL Technology?

The massive size of 3D CAD data is a bottleneck that keeps it from being used outside of design. XVL (eXtensible Virtual world description Language) is a 3D ultra-compression technology that was born to resolve this problem. It reduces the weight of the 3D data so that anyone can use the data easily. Thus, it offers a wide range of opportunities to manufacturing. With XVL, design assets which took enormous costs to build can be used to improve efficiency throughout the enterprise.

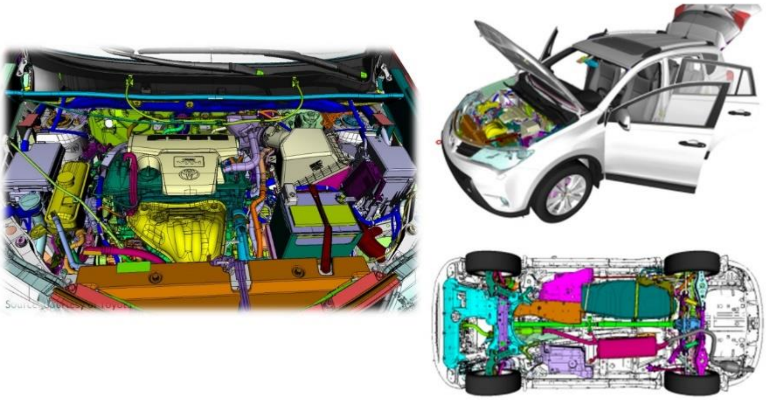
Technically, data can be made lightweight in two ways:

1. **Reduce the data size.** This allows 3D information to be sent to regions with low bandwidth connections.
2. **Reduce the display requirements.** This enables larger volumes of 3D data to be displayed on standard computers.

XVL uses both approaches. It uses curved surfaces to reproduce the original data in a highly-compressed format while maintaining accuracy with the original model.

The figure below shows a full-scale model of an actual car developed at Toyota. While the CAD model of the vehicle is about 20 GB, the XVL model about 250 MB, or 100 times lighter.

Figure 3-2: Complete automobile model in XVL format.



20 GB 3D CAD data reduced to 250 MB XVL data.

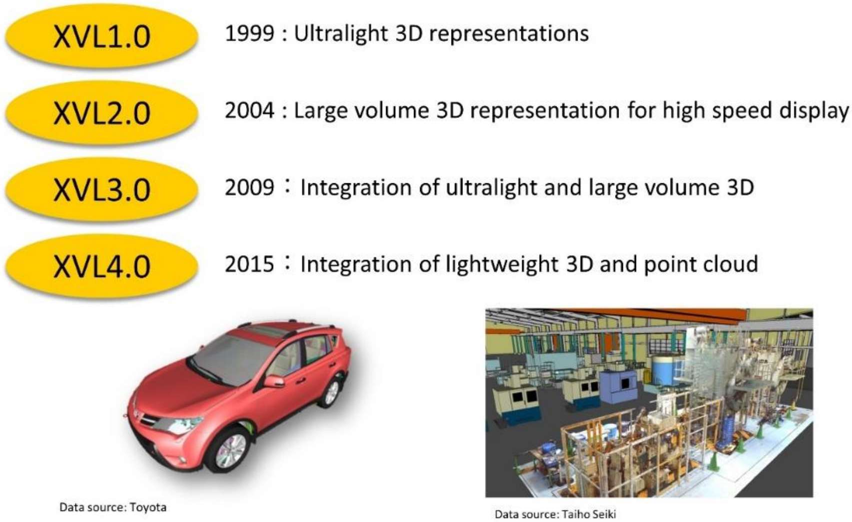
Such a small data size allows the whole vehicle to be displayed and manipulated on a standard PC. Even for assemblies with fewer parts, designers are usually forced to segment the design into subassemblies. Even loading subassembly with a modest amount of parts might require a coffee break for it to load. Segmenting the "whole product" into sections of subassemblies diminishes the value that is possible when working with the complete product. The ability to display and manipulate the whole model means that tests and analyses can be performed immediately using the 3D model instead of having to build the prototype.

The reduction of data size to 1/100th of the original size also means that the network transfer speed can be improved by 100 times. This enables applications like interactive 3D work instructions. With 3D CAD, even small assembly processes can use several hundred MB of data. Using XVL reduces the data size by a factor of 100 and enables even complicated 3D animated work instructions to be shared over the network.

History of XVL Technology

XVL, the 3D compression technology developed by Lattice Technology, has evolved four times. This evolution of XVL was triggered by the advancement of information infrastructures and changes in user needs. The following drawing shows the history.

Figure 3-3: Evolution of XVL Technology



Evolution of XVL technology from ultra-lightweight 3D model
to integration of virtual 3D and point cloud data of actual objects

In the mid 90's the internet started to take off and grow rapidly. New data types such as images, sounds, and even video were being added to web information. This also marked the start of video streaming. People then thought the age of 3D information would soon follow, but surprisingly it did not.

In the 90's, there was a standard 3D data format called VRML (Virtual Reality Modeling Language). Given the limited network speeds and processing power available at the time, the amount of VRML 3D data that could be streamed and displayed was limited. For instance, people's heads and bodies might be represented by spheres and cylinders. The network infrastructure was far from being able to transmit and display 3D CAD models. These limitations prompted Lattice

Technology to develop XVL technology to resolve this problem.

[XVL1.0] Birth of 3D Data Ultra-Compression Technology

When we first embarked on the development, our dream was to "change the world with 3D." We set our sights on developing 3D models that were 100 times lighter in the belief that this would enable sharing of 3D data over the Internet. We anticipated that this would lead to a fundamental change in how work is done in the manufacturing industry, bringing about beneficial changes in the world with the use of 3D data. From the beginning, we expected this to work.

XVL works by creating a patented lightweight representation of the CAD surfaces. CAD models are made up mainly of curved surface data. By eliminating this curved surface data, or by replacing it with a lighter representation, it was possible to dramatically reduce the size of the data.

The basis of this idea is that simple curved surface shapes can be interpolated from peripheral curved surface shapes. If simple curved surface shapes can be interpolated within the specified accuracy from boundary curve data of surrounding edges, it means that curved surface data can be deleted. We tried this and found it to be very effective. That was the moment when expectation changed to the strong conviction that the technology would work. We went on to enhance the combination of mathematics and compression techniques and finally succeeded in 100 times compression.

At the time XVL was born in 1999, the Internet was mainly connected using telephone lines. The network speeds were slow compared to today. In such an environment, the use of XVL helped transfer large volumes of shape data. I remember people gasping with excitement when we used to show them demos of XVL back then. On the other hand, we started to realize that XVL was born too early, that the world was not prepared to change with XVL alone. There were almost no companies designing all the parts of all their products using 3D CAD.

[XVL2.0] Representation and high speed display of large volume 3D data

"What's the point of using 3D CAD if the 3D CAD system cannot display the whole 3D CAD model? Can XVL not resolve this?"

These words spoken at Toyota helped change the course of the next XVL evolution.

Toyota had recently adopted 3D CAD throughout their manufacturing process and spent an enormous amount of time on CAD training, but the volume of 3D data that was created turned out to be so massive that the CAD system could not display the vehicles. At the time XVL was optimized for sending data over the Internet. It was not suitable for displaying large volumes of 3D data.

In the early 2000's, 3D CAD started to rise in popularity, and more and more manufacturers started to design whole products using 3D CAD. The resulting 3D models were massive -- a piece of office equipment was several GB and for an automobile could be more than 10GB. PCs in those days had memory that was not more than 2 to 4 GB, so of course, they could not display complete 3D CAD models.

So, the bottleneck had changed from network environment to memory capacity. The technical challenge here was to enable the display of massive volumes of 3D data that exceeded several times the capacity of the PC memory. Moreover, the data had to be displayed very quickly for practical applications. Setting our next target as displaying a whole vehicle on a standard PC, we started thinking of ways to reduce the memory and data structures which could maximize the graphics performance of PCs.

In this way, in 2004, we expanded XVL representations using a totally different approach, resulting in the birth of XVL2.0. Now, XVL models were all derived from CAD models. Up to this point, our goal in the development of XVL was for it to represent CAD models as accurately as possible. Now, we expanded the purpose of XVL to include representation of data which cannot be represented by CAD models.

[XVL3.0] Achieving both compression and ultra-large volume 3D data

Amidst the economic chaos that financial crisis in 2008, the XVL development team at Lattice Technology was busy taking on the challenge of integrating the world's top 3D data compression technology and large volume 3D functions, and achieving the advantages of both in a single format.

This endeavor was in response to two common user requests for the development team. One was the need to share 3D information even in regions with poor network infrastructure. In other words, further compression of 3D data was required. The other need was to be able to use even larger 3D data models for verifications because products were becoming larger and more complicated. Specifically, users wanted to be able to easily verify products being developed using 3D data as digital mockups instead of using prototypes.

To meet these needs, we had to further reduce the XVL data size to be able to transfer large models over low bandwidth connections. At the same time, we needed to be able to display large models quickly and manipulate them smoothly. We had developed two versions of XVL specialized for each purpose. In 2009, we integrated the two XVL formats and achieved the benefits of very small data size and smooth display of large models at the same time. This produced a new XVL version with the best basic 3D functions in the world. Today it is being used by leading manufacturers worldwide.

[XVL4.0] Integration of virtual lightweight 3D models and real objects

In the age of IoT, everything will be connected to the internet, allowing diverse information from sensors to be shared in real time. It is expected that this will lead to the fusion of virtual and reality, where virtual data will be integrated into real scenes. One example of this is the use of 3D data at plants to compare the original 3D models (as designed) and determine the changes (as maintained), as well as to plan and validate future changes.

Today, laser scanners and PCs can scan and display large volumes of point cloud data. However, scanned point cloud data is generally too massive to be used in product design and manufacturing departments.

XVL4.0, which was released in 2015, can restructure point cloud data and integrate it the same way that it integrates assembly information in CAD models. This turns point cloud data into point cloud models, making it possible to compare 3D models to 3D scanned objects. In this way, XVL has evolved into an ideal platform for merging the virtual with the real.

Casual 3D World

This section introduces the concept of Casual 3D made possible by XVL1.0.

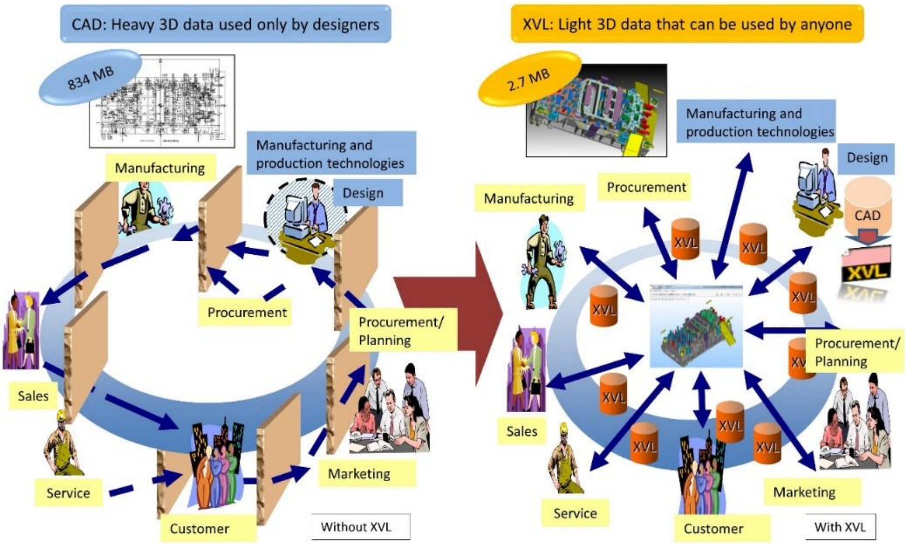
3D CAD has become common in the manufacturing industry, but its use is generally limited to the design and production engineering departments because of its high cost and the need for high-end computers, and sophisticated training. In the manufacturing industry, only about 5 to 10% of employees in the company are in departments which use 3D CAD. This means that 90 to 95% do not have access to the 3D CAD models.

By compressing the data to 1/100 of its original size and providing an environment for everyone to access the data, XVL1.0 enables what we call "Casual 3D."

The concept of "Casual 3D" is that anybody can access 3D models and use them in his or her work. Until now, as it has been difficult to use CAD models as they are; the design department had to convert them into 2D drawings so that staff in the downstream processes can refer to the drawings in their work. The goal of Casual 3D is to do away with these 2D drawings and allow work to be carried out based on 3D models. In the manufacturing process, such tasks as planning work procedures, giving assembly instructions and creating exploded views for illustrations have been performed using 2D drawings and prototypes. With Casual 3D, these functions can be performed easily and naturally using 3D models.

The following drawing shows the model of mold manufacturer Tsubamex, who will be discussed in Chapter 5. Sharing enormous 3D CAD models was not possible, but sharing lightweight 3D XVL models was easy. Information sharing using lightweight 3D models eliminates the barriers between organizations and promotes collaboration between departments.

Figure 3-4: Casual 3D made possible by XVL.



Casual 3D : Enhances work processes by releasing 3D data used by designers to the whole organization.

XVL Supports Manufacturing Collaboration

XVL started as a 3D geometry representation. For XVL to contribute to the manufacturing industry, it was crucial for it to evolve beyond that. The addition of non-geometrical elements to XVL has made it much more useful in the manufacturing process. This section describes how non-geometrical XVL data can be used and introduces different XVL software products on the market.

In manufacturing collaborations using 3D design data, information can be distributed using 3D models instead of drawings. In some cases, manufacturing activities can be started once information such as the required mold geometry, machining method, machining accuracy is available. In such cases, XVL can include 3D dimensions and annotations. XVL can also change the colors of geometries to signify different information to different departments. One example of this is that mold companies are using colors to specify the machining methods for parts, shapes, and surfaces. In the past, different colors were used on 2D drawings to provide information about the machining methods. Today, 3D models are drawn using different colors so that engineers can understand the machining methods intuitively. To support these activities, Lattice developed the XVL Studio tool to edit colors and structures, show measurement results, and add comments. In 1999, Lattice released XVL Player, a free viewer that enables users to easily view data on PCs at the manufacturing site. With the spread of tablets and smartphones, in 2011 Lattice also released iXVL Player, a free viewer for iPad and iPhone. This has helped accelerate manufacturing collaborations using XVL.

XVL: Bridge between Design and Manufacturing

From the beginning, XVL was good for displaying product shapes for manufacturing. However, it quickly became clear that the 3D display of objects is not sufficient. Why was this? It is because different users need different information. Manufacturing technicians are usually interested in the assembly order of their own work, while service engineers are mostly interested in replacement of complete parts and modules. Furthermore, the model structure is defined by designers and differs from that required by the manufacturing and service departments.

In response to these user needs, structural information such as manufacturing units, assembly order, and service units was added to XVL. This enables users to display products in the desired form and structure in 3D, independently of the structure that the designer created.

In this way, these improvements resulted from the need to resolve fundamental problems of 3D CAD. 3D CAD is optimized for design but not to support post-design usage and collaboration. Addressing this issue enabled XVL to bridge the gap between design and manufacturing.

“One file PLM” Provides PLM Information to Downstream Departments

The PLM system in the design department manages the design information, but from the perspective of downstream departments like manufacturing, it can be difficult to access, complicated, and unaffordable. Also, downstream departments have other needs such as processing the information for work instructions, adding information for inspections, etc.

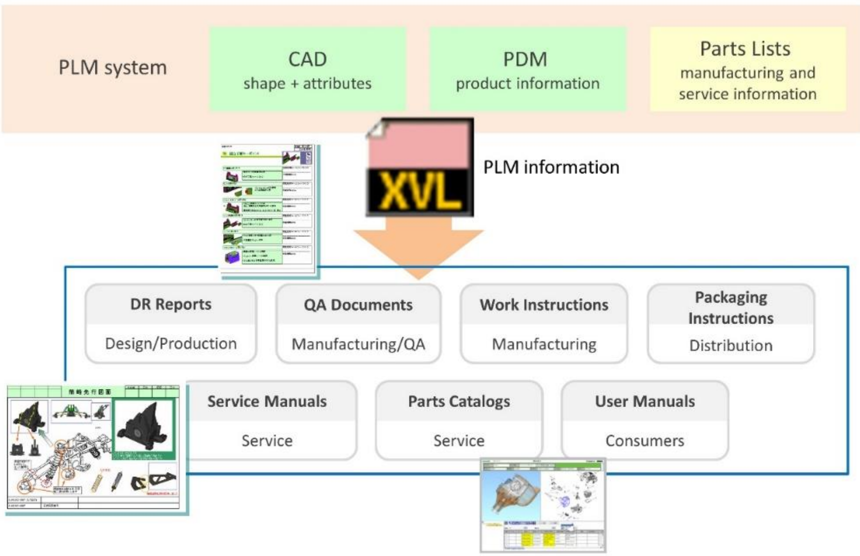
One way to avoid the use of PLM is to pack all the required information into XVL, send it downstream and process it in the downstream departments. This idea is called “One file PLM.”

To enable “One file PLM,” Lattice developed a way to store bills of material (BOMs) into XVL models. XVL files can include multiple bills of material, such as manufacturing BOMs (mBOMs) and Service BOMs (sBOMs). In this way, an XVL file can convey advanced PLM information. By combining these multiple BOMs into a single file with XVL’s ability to be accessed from a number of clients, the usability of the 3D data once locked away in engineering has exploded. This means that a single XVL model can be used to show 3D instructions on spreadsheet-based work procedures at the manufacturing site, display parts catalogues on an iPad to identify faulty parts during servicing work, and so on.

As shown in the illustration below, various documents required for manufacturing can be prepared from XVL models packed with all the required information.

With XVL, the “One File PLM” concept enables manufacturers to convert PLM design assets into company-wide assets that can be used to improve quality, reduce costs and shorten delivery times.

Figure 3-5: Manufacturing documents created from "one-file PLM."



The "one-file PLM" concept enables manufacturing documents to be created from PLM data.

XVL Models Replace Prototypes

XVL2.0 allowed any manufactured products such as automobiles, construction machinery, farming machinery, etc. to be visualized in 3D. The next requests from the design, production, and engineering departments were to be able to use the models for design verifications.

For example, engineers might want to see how products will operate. To do this, they need to be able to move a certain part and see how the parts move together. To support this, XVL3.0 included a function which can express mechanism information for showing how parts move together. In prototypes, these movements are controlled using control software. To enable XVL models to be driven using control software, we developed the Vmech tool.

At the same time, the verification of the electrical characteristics of products requires information such as the location of conductors and insulators and the electric potential differences between parts. At the time it was necessary to construct and test prototypes to get such results.

To meet these needs, Lattice Technology teamed up with top electrical and electronic-control CAD manufacturer ZUKEN to give electrical characteristics to XVL models so that they can be verified on digital models.

These enhancements have turned XVL into a digital test platform. By adding such information to the 3D models of products, digital XVL models are becoming closer and closer to real things. In other words, the "CAD+1" concept is becoming increasingly real. Using XVL digital mockups instead of prototypes accelerates the design process.

XVL Supports Multi-CAD Environments

Many manufacturers use multiple CAD systems for the same product. Sometimes this happens because of companies being merged or acquired. In other instances, different departments choose different CAD systems based on their suitability for their specific types of design. One example is an elevator manufacturer that needs to use construction CAD for buildings and manufacturing CAD for products. Moreover, given the increasing demands for the electronic control of elevators, there are growing needs to integrate electrical CAD data with manufacturing mechanical CAD models.

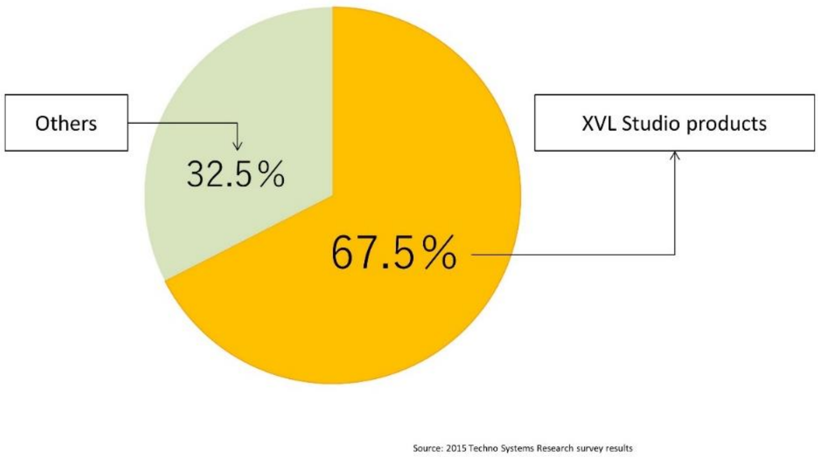
In environments using different types of CAD software, collaboration across different departments are naturally more complicated. XVL can resolve most of these problems. In the elevator example, mechanical CAD data, as well as most construction and electrical 3D CAD, can be converted to XVL, and the models can be digitally verified together.

By converting different types of CAD data to XVL, digital mockups of products and virtual factories can be quickly integrated. Also, XVL4.0 also supports 3D point cloud data and enables 3D scans to be added to models.

XVL: The Most Popular 3D Lightweight Technology

With the growing need for 3D data in the manufacturing industry and increasing use of 3D in education and training, XVL is spreading in the manufacturing industry as a lightweight 3D viewer. XVL offers two distinct advantages over other common 3D viewers: 1) Accuracy and 2) Inclusion of related information in the context of the 3D model. Per a 2014 survey by Techno Systems Research, XVL accounted for 67.5% of the market share in Japan.

Figure 3-6:   XVL rapidly becoming standard in viewer market.



With the evolution of information infrastructures and globalization of the manufacturing industry, needs for lightweight 3D technologies are growing even more. This can be seen from the following three perspectives.

1 Growing volume of 3D data

With the emergence of high performance PCs and growing popularity of 3D CAD, detailed structures such as screws and slits are now being included in 3D CAD models. The demands of globalization are also increasing the generation 3D data. Products are also becoming more complicated, as seen for example in the combination of gasoline and electric motors in the case of hybrid vehicles. The assembly processes of complicated products are themselves complicated. New attributes are needed to express more complicated work procedures, leading to increased information volume. Information handled by “One file PLM” therefore just keeps on increasing.

2 Growing needs for data lightness

More and more of us access on tablets and smartphones these days instead of PCs. While PCs today feature large memories, tablets and smartphones intended more for personal use have small memories. Here, once again XVL is useful for displaying 3D on such devices due to its lightness and simplicity.

Most plants today have clean rooms. PCs are not allowed in these clean rooms as their fans blow out dust, but iPads can be brought in as they do not have fans. Using iPads, work instructions using 3D information can be referenced in clean rooms.

3 Security indispensable to global data distribution

Some time ago, when I visited Japan Business Federation, I had a chance to explain XVL to the chairman at that time. The first thing he said to me was “security is crucial for 3D data. Otherwise, all our important 3D information will easily be leaked to competitors”.

With global production, it is necessary to send 3D data overseas. Needless to say, the distribution of CAD design data carries risks of design knowledge being stolen and used to produce identical counterfeit parts and products. XVL can resolve these concerns in that it can conceal design knowledge and reduce geometrical accuracy. XVL also has reliable security solutions to prevent data leakage.

Current trends require 3D data to be even lighter. With XVL models evolving to the point that they can replace prototypes, they have even more roles to play in the manufacturing industry today.

XVL Becoming the “Intelligence” of Manufacturing Industry

Information is the amalgamation of fragments of data. It does not express facts systematically. Intelligence, on the other hand, is the integration of information and it serves as the material or source of various ideas and judgments. It is, in other words, the source of knowledge.

By integrating 3D models and accompanying design and manufacturing information, XVL changes information into intelligence. The 3D scanning of real-world objects allows them to be used as models for information integration in the world of XVL. Unlike simple digital mockups, XVL can serve as the “source of intelligence” to companies.

With the arrival of the IoT age, we are now increasingly able to collect data on the manufacturing process from various sensors and automatically detect quality problems, allowing manufacturing quality and efficiency to be controlled. Eventually one day, factories will have zero defective products and be able to manufacture the required products in the required quantity. The availability of big data allows judgments to be made for various problems with AI and deep learning, but right now, we have not come that far in that the data available is still limited. In this situation, XVL is useful for making correct judgments from the visualized data. In this way, the presence of XVL will play a very important role in the near future as a “source of intelligence.”

XVL has steadily evolved and been made tougher through the challenges faced at the manufacturing sites all over the world. Now that enormous amounts of 3D data can be shared on networks, and the information required for design and manufacturing can be obtained from this gigantic pool of data with XVL, some leading manufacturers are starting to use XVL as their company database and optimize their manufacturing process using 3D data for all their operations. The next chapter focuses on some of these pioneering companies who are using XVL as their “source of intelligence.”

Chapter 4: Strategies for Using 3D CAD Data to Support Global Manufacturing

Applications of 3D CAD Data by Manufacturing Companies

To achieve global collaborative manufacturing and the ultimate concurrent engineering, pioneering manufacturing companies are already actively using 3D CAD data in their business activities and achieving significant results. In many cases, these companies are using lightweight 3D data technologies like XVL to overcome downstream challenges using 3D CAD design data.

One manufacturer of agricultural machinery has trained their staff on the use of 3D data so that they can all review virtual 3D models of their products like tractors on their PCs in the office. For those working at manufacturing and sales departments, it would be convenient if they could see and touch the latest tractors, but realistically, it is impossible to display the actual machines in the office. 3D XVL models, on the other hand, can be placed anywhere and allows staff to review machines from various perspectives, and plan future manufacturing processes. This marks the start of the use of 3D CAD data in manufacturing.

3D CAD data enables digital mockups to replace most product prototypes. For example, now at car manufacturers, experienced staff can predict the areas of a car where water leakage will most likely occur with just one glance at the cross-sectional 3D models o`f the car. Not only does this identify issues before a prototype is built; it also minimizes the number of prototypes required.

This chapter highlights key solutions for using 3D data in manufacturing including case studies of the pioneering uses of 3D data. The key solutions are:

1) Design review
2) Assembly process design and verification
3) Verification of control software
4) Verification of maintainability
5) Work instructions
6) Parts catalogs
7) Illustrations

Lightweight 3D Solutions (1): Minimizing Product Costs using Design Reviews

It is said that 80% of a product cost's is determined in the design stage. Considering the total costs required during the life cycle of a product, ensuring quality in the design stage is very important. In other words, if quality problems are discovered in the manufacturing stage or on the market, the costs incurred to resolve the problem will be enormous. Therefore, building design and manufacturing process that discovers problems early can help reap long term corporate profits.

However, given the product recalls that are reported in the media with great regularity, there seems to be considerable room for improvement in the design stage. To enhance manufacturing quality, many manufacturers have been shifting from design reviews (DR) using drawings to design reviews using the 3D models. Problems which cannot be discovered just by reviewing drawing can often be automatically detected using 3D data.

With 3D design being so common, DR using 3D models is an effective means of preventing such problems. Particularly for products with complicated mechanical structures such as automobiles and industrial machines, there are problems which cannot be detected just by reviewing drawings. Computers can now perform automatic checks of interferences and clearance between parts using 3D models. By leaving such simple checks to software programs, designers can concentrate on making judgments and creative work. High quality can be achieved from the design stage by letting computers check 3D models of designs and detect problems, which can then be corrected by designers.

Review of Large-Scale Product Achieved by XVL

"This is the first time I see the product I helped design…" These words are often spoken by designers participating in design reviews of large-scale products using XVL. Most modern products such as automobiles have complicated mechanical structures. Designers in charge of designing the respective parts of such products use 3D CAD to design the parts they oversee and can review these parts using 3D data, but due to the massive data volume, it is usually difficult for them to see the whole automobile which they helped design on CAD.

However, with lightweight 3D technology such as XVL, designers can review complete products and speedily display what they want to see from any desired angle. Although this has been difficult to do for large-scale products using 3D CAD, there are now XVL solutions which enable designers to swiftly determine problem areas by looking at the whole products, find problems, display the cross-sections of the issues, move some product parts or review them in detail, and keep records of such problems in 3D. Since the purpose of DRs is to resolve design problems, problems must be fed back to designers accurately for them to make the necessary corrections. For this reason, keeping records of problems in 3D is very important. Also, sharing information on such problems in 3D is an effective means for maintaining accurate communication at the work site.

XVL's DR solutions can automatically detect, document and display all the interferences in the product in one pass. Clearances between parts can also be checked in the same way. Interfering parts can be differentiated using colors per the distance between the parts so that problems can be followed up at a glance. Moreover, this clearance function is also useful for discovering problems such as wind noise caused by gaps. In this way, DR solutions are also contributing to the enhanced quietness of hybrid cars and electric vehicles.

The 3D data of interferences can also be linked to corresponding images in action plan tables, allowing those involved to decide who is to take what action and by when; share this information and link it to the next action. By establishing and making the DR process routine in the organization, it will be possible to achieve high design quality in the upstream process. In this way, the culture of giving priority to quality is incorporated into the company's DNA.

Design Reviews Performed at Toyota

The XVL DR solutions were developed jointly between Lattice and Toyota based on Toyota's requirements. 3D design reviews are discussed in detail in the previous book "3D Manufacturing Innovation" (published by Springer), so only the highlights will be mentioned here.

Toyota carries out two types of DRs: sheet metal DR and DR of all parts. First, interferences between metal sheets are checked, followed by interferences between all parts. This interference between parts is carried out carefully for each door, body panel, etc. First, the team preparing for the DR prepares the 3D models and then runs automatic interference checks. All problems are listed, and DR review meetings scheduled and attended by all involved to resolve the problems as soon as possible.

Toyota uses DR reports, which they call management sheets, to manage all their activities. They work on each problem and resolve them completely. Problems are listed in the sheets and checked off when they have been resolved and a procedure to check for that issue in the future has been decided. Determining the preventive measures for each problem on the spot in this way is thus Toyota’s key to a successful DR.

Once those in the design department experienced successful DRs using XVL models, they discovered that XVL models might be useful for purposes other than resolving interference problems. The additional applications includes reviewing the optimum layout of cables and wires, assembly work efficiency, clearance with movable parts, fitting, abnormal sounds, appearance, etc. They found that with XVL, staff from different departments can review product designs together, i.e. check products together and resolve any problems on the spot. For instance, it is difficult to tell just from drawings how the corner lights of a car would look through the glass. By using XVL at the manufacturing site, the sideways appearance of such corner lights can be reviewed on 3D data.

Lightweight 3D Solutions (2): Assembly Process Design and Verification

Chapter 2 discussed the importance of production technologies. The production engineering department resides between the design department and factory, and it has the crucial role of proposing manufacturing processes and methods for manufacturing high quality products efficiently. In general, the production engineering department indeed plays an enormous role in the coordination between design and manufacturing.

Modern products continue to grow more and more complicated, and their production procedures more and more sophisticated. Today, many manufacturers place their design and production departments in different countries, which means that the production engineering department must have skills to coordinate the two departments across languages and borders. Support using IT is thus important. Some of the problems faced by production engineering department include how to provide support for concurrent engineering, and how to capture the intuition and knowhow of experienced staff and pass it to future generations.

To launch production quickly, the production engineering department must design and verify production processes based on design information. Use of 3D design models for design enables the assembly procedure to be determined, problems in parts assembly to be visualized, and the results to be fed back to the design department as soon as possible. Completing the correct process design at an early stage, enables factories to be launched vertically.

At most manufacturing sites, the assembly procedure is decided by experienced staff using their intuition and knowhow. However, most of the time inexperienced staff cannot intuitively understand why the experienced person came up with a certain idea and why that idea was successful. However, when the work of such experienced staff is observed carefully, sometimes even these experienced persons are not confident of what they are doing. No one can judge if a particular method is the most efficient method available. With less and less experienced persons in the present manufacturing industry, it would be more effective to clarify the work procedure using 3D models, verify the suitability of the procedure, and define efficient standard work processes. It is in such areas that lightweight 3D data proves useful.

Visualizing the Assembly Order using 3D Models

CAD is a tool for defining shapes; it cannot define the assembly order of products.

Generally, 3D CAD models are expressed using the structural information of products and 3D shape information of parts. XVL not only makes 3D models lightweight but also provides the structural information of products and assembly order information. To share the assembly procedure globally, it is advantageous to define the procedure on 3D models.

Here, “assembly order definition” is the process of deciding the order by which parts are assembled. In many cases, the assembly order is defined using spreadsheets. Some companies define it inside the parts table. XVL solutions can import external assembly order data and enable definition of the assembly order while viewing the 3D model interactively.

This produces a 3D visualization of the assembly procedure, which is very useful for collaborating with the design, production engineering, and manufacturing teams.

What are the advantages of sharing assembly order using 3D data? The following are the three advantages of defining the assembly process using 3D data.

1) Processes can be reviewed earlier, allowing the work schedule to be moved forward.
2) By visualizing the assembly process design with interactive 3D, the skills and know-how of experienced persons can be passed onto younger generations.
3) Since the designed assembly order can be displayed using 3D data, work procedures can be conveyed globally across national borders.

Creating the assembly order definition is very time consuming. When developing new versions of a product, companies would like to leverage the definitions for the previous generation. This is possible with XVL. Companies can use the XVL models of previous designs, or of designs in progress, to start assembly process planning before the current design is complete. In this way, they can shorten time to production.

Often global manufacturers will design their production process in one country and carry out production in another. In such cases, there is often a need for cross-language cooperation between production engineering and the overseas factory. If the production process is defined with XVL, then it can be easily shown using interactive 3D animations. This makes it possible to understand the production process without needing to understand the original language.

Accelerating Product Development

In product development, first the design is determined, followed by the product structure, parts names, and shapes. As the product design matures, the 3D design data can be used for downstream process verifications such as assembly sequences, clearances, and tolerances. If process reviews can be accelerated using 3D data, then any defects that are uncovered can be quickly fed back to engineering, and the model can be fixed before the 3D design finalizes.

The following two methods are useful for reviewing processes using 3D data.

1) Assembly Review: Verify that products can be assembled correctly per procedure.
2) Workability Review: Verify that the work can be carried out easily and safely by humans.

An assembly review checks that parts can be assembled smoothly according to the procedure, whether parts and tools interfere with other parts, etc. Parts are moved along the specified assembly paths and checked for interference, and the distance between parts is checked in real-time to confirm that parts can be attached smoothly.

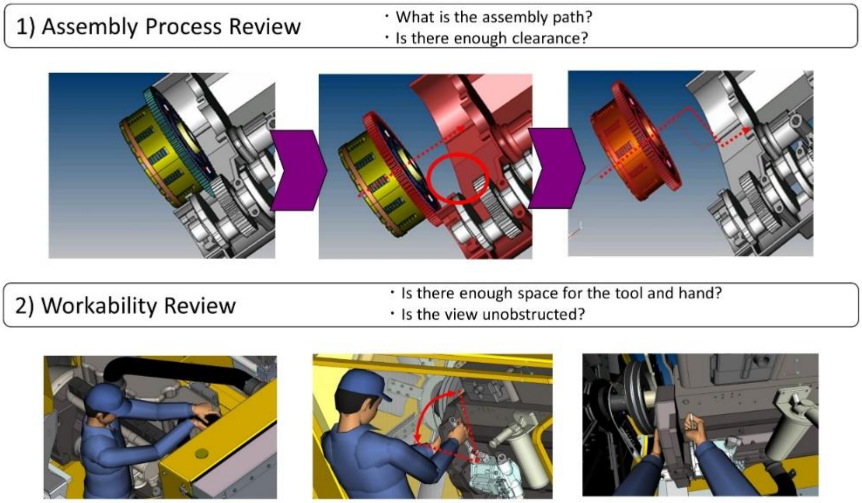
A workability review checks that tools and hands can enter a certain place using human models and whether the posture at such times is suitable. This means checking “what can the operator see” and whether “excessive burden is imposed on the worker.” Such review work is increasingly important for avoiding labor disputes.

XVL also has a function that can take snapshots of specific

3D model states. Working in XVL, problems can be detected; comments can be added to the 3D model, and 3D interactive snapshots of those areas can be captured. The snapshot can reproduce the same state of the 3D model. Thus it is useful for devising solutions between the stakeholders for the concerned tasks and challenges. Recently, more and more manufacturers are dividing product assembly work around the world. In some cases, it is more efficient to divide assembly process design between foreign and domestic offices. This division of the assembly process design can be supported using XVL solutions. By integrating processes which are defined in each office, the total assembly process can be defined across national borders.

Below are examples of each method.

Figure 4-1: Process verification using XVL models.



Mitsubishi Mahindra's Challenge in "Producing at the Same Speed as Selling"

Mitsubishi Mahindra Agricultural Machinery designs and sells agricultural machinery such as tractors and combines. The company uses 3D models to reduce the development lead time from planning to production. In addition to 3D CAD design data, the company applies XVL-based 3D solutions in their process design. They started using XVL to achieve their build-to-order goal of "designing and manufacturing quickly when customers order the products."

Prior to using XVL, those in charge of preparing for production at Mitsubishi Mahindra compiled work instructions by envisioning the assemble process in their minds based on design information. However, they found that carrying out production preparation work while waiting for information on completed designs was just too slow for "developing products at the speed of selling them,"

Only experienced staff could carry out this task smoothly. Moreover, since not all stakeholders could not conduct reviews halfway through the design stage, this method also had problems of passing down skills to other staff at the company. For these reasons, the company decided to adopt the XVL-based solution so that they can check the progress of assembly work halfway through the process using 3D models.

This solution has enabled them to start production preparations earlier by reviewing the assembly process using 3D shapes of products which are in development, reviewing the required tools, etc. Since XVL also shows how experienced designers planned the assembly process in 3D, the designers can grasp the whole process beforehand and use that knowledge in product design. Also, the XVL solution also enabled production preparation skills to be passed down to others more easily.

Those in charge of process design at Mitsubishi Mahindra often say that they prefer using XVL to the conventional approach and that they "never want to go back to the conventional method." XVL has become an essential tool to them, and the "visualization of the assembly process review process" has been established at the workplace. Per Masashi Kawamoto of the Development Management Group of the Business Department using this system, "the success of this system has led to the motivation of our staff to change future assembly process design and work specifications."

Also, to achieve the challenge of "producing at the same speed as selling", the company has switched from their conventional method of lot production to mixed production of diverse products. With this method, many diverse products are produced by the line. In this way, the products that customers need now can be produced now.

By applying the XVL-based 3D solution for preparing work instructions for this mixed production method, the company also succeeded in enhancing information sharing between departments and shortening work time. Since the process is defined together with the 3D shape data, work instructions can be created semi-automatically. The completed instructions are then adjusted to the characteristics of the manufacturing site and can be referred to on paper, laptops, and tablets. In this way, by sharing assembly process information and preparing work instructions using XVL data, the company is steadily accumulating the skills and knowhow for releasing products onto the market at the "speed at which the products sell."

Lightweight 3D Solutions (3): Facility Development Optimization with Control Software Verification

In the manufacturing process, once product development completes, mass production starts. In many companies, development of the mass production process is an untapped treasure trove. This is because while many such companies apply concurrent engineering to their product development process, few apply concurrent engineering to their facility development process. Moreover, although some companies design their manufacturing facilities using 3D CAD, only a few of them perform thorough verifications of the facilities. By developing high quality mass production facilities, companies can quickly achieve mass production and quickly implement production changes as product designs change.

Enhancing Flexibility of Mass Production Facilities using Control Software

Manufacturers are increasingly implementing small-lot production processes of diverse products to meet the ever-changing needs of consumers. To produce diverse products, mass production facilities must be able to operate flexibly. Consequently, more and more manufacturers are starting to control mass production facilities using software programs and PLCs (Programmable Logic Controllers).

The PLC was developed in the 60's in the U.S. for controlling production lines in the automobile industry. Given that automobile production facilities consist of various control circuits, it takes considerable time and efforts to change these circuits each time a new model is brought out. PLCs were thus developed to automate release of new models using software. PLCs are used widely in the manufacturing industry due to their universality, ease of change, robustness, and reliability. Recently, high performance CPUs have been added to further broaden PLC capabilities. Mass production facilities run by PLCs are controlled through software.

Verifying Mass Production Facility Control Software Using 3D Models

3D CAD is increasingly being used by manufacturers to design mass production facilities. First, mechanical designers design the mechanism of the facilities, how the parts of the facilities should work, and eventually how the facilities should operate, and then design their 3D shapes. Based on this, the control software developer prepares the PLC program and specifies the actual mechanical movements. After the actual facility is completed, the software developer uses the facility to verify the software. In this stage, as the actual facility has already been completed, if defects are discovered, they can only be resolved by correcting the software one way or another. Moreover, if the delivery deadline is tight, the software developer only gets to see the actual faculty for the first time during installation at the overseas factory.

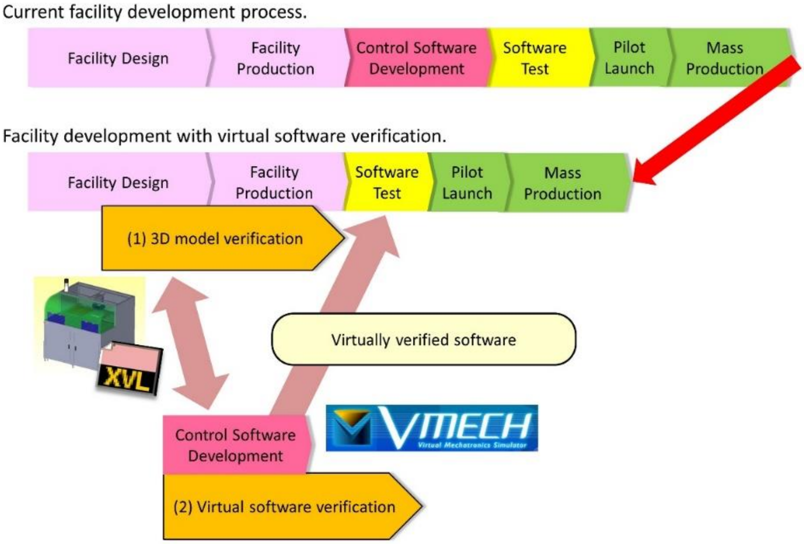
With the continuous increase in PLC performance, now many types of mechanisms can be controlled. This has led to the increase in the scale of control programs, but it also means that the time and effort for debugging have also increased. Like general software development, workload such as debugging and tests increases. To resolve this problem, Vmech was developed as a solution for verifying software using XVL as a virtual facility model instead of the actual facility. Since the mechanisms of virtual models are defined, their operations can be controlled by PLC programs like actual facilities. This solution is seen to offer the following advantages to both the mechanical design department as well as the software development department.

Advantage 1: The mechanism design department can use a 3D model to check the operations, enhancing design quality of the drive unit and mechanical parts.
Advantage 2: The software development department can focus on debugging work using 3D models instead of the actual facility.

The largest advantage is the fact that everyone involved, including mechanism designers, control software developers, and factory workers can share images of facility operations. In this way, PLCs play an important role in the use of IoT in the manufacturing industry.

The following section details the benefits of XVL-based facility design and verification at Brother Industries.

Figure 4-2: Facility development optimization with virtual software verification.



Optimize facility development by verifying control software virtually using 3D models.

Brother Industries Achieves Speedy Factory Launch

Delivering products “just in time” is crucial for winning in global competitions. To achieve this, global manufacturers need to be able to promptly reconfigure the facilities of their plants around the world. The production engineering department at Brother Industries uses PLCs to enhance the work efficiency and operating rate of their mass production facilities. They use the control software running on PLCs to control the operations of their facilities. Until now, the company had to connect the PLCs to actual facilities to verify the control software. However, this meant that software developers could only carry out software verification after the facilities were ready. Moreover, debugging work on actual machines is accompanied by the following problems.

1. As actual facilities are shared by engineers, they need to

adjust the schedule for using the facilities in turns.
2. If a mechanical part becomes damaged due to a bug, it is necessary to wait for it to be repaired.

These problems can easily be resolved if the debugging work can be started immediately without using the actual machine. Brother Industries decided to debug the control software for an actual manufacturing site using the XVL-based virtual mechanism simulator Vmech in a virtual environment. The reason they chose Vmech is that XVL enables high speed simulation and visualization even for large-scale, complicated production facilities.

Vmech produced results that were greater than the company had expected.

1. Performing debugging using Vmech sharply reduces the software correction time on the actual machines.
2. As the operations of facilities can be checked on 3D beforehand, the actual machine can be installed on-site much more smoothly.

Shinichi Suzumura, Senior Team Manager of the Production Technologies Department at Brother Industries, says that “we hope to use XVL for simulation in the next step even when several facilities are linked, to achieve further increase in efficiency.”

In this way, Brother Industries is performing software verifications using XVL to help launch plants rapidly and quickly achieve mass production with limited manpower.

Lightweight 3D Solutions (4): Maintainability Verification with Virtual Prototyping

Many manufacturers of large products such as automobiles and industrial machinery are making huge profits because they can provide maintenance services for their products themselves. Looking at the structure of these industries, for example in the case of automobiles, automobile manufacturers employ thousands of staff all over the world to carry out the disassembly, adjustment, and assembly of cars. It is thus crucial for them to review the means of improving the efficiency of these tasks to provide efficient support to their employees.

In the assembly of cars, normally car engines are inserted from the bottom of the car, but during servicing, they are removed from the top. This is because after the engines are mounted, many parts and harnesses are installed after them, making it very difficult and time-consuming to remove the engines from the bottom again. For this reason, prior to mass production, car manufacturers need to view the serviceability of the engine and these parts in future maintenance work.

If the task of removing the engine is a complicated and laborious process, it not only means that the work of all those thousands of service personnel will also become more difficult, but it will also increase the costs for the car owners. Currently, most automobile manufacturers perform maintainability verifications such as whether the care can be disassembled, whether water is leaking, whether the piping can be moved easily, etc. using the actual cars. With this method, if problems are discovered during verification, the cost to change the design to fix the problem is enormous. For this reason, recently many leading manufacturers have started to use 3D models for maintainability verification and are shortening their lead times.

For example, ease of disassembly can be judged from 3D models by checking such points as whether the tools required for disassembly can fit inside the car or if there is sufficient space for this. If complete 3D models of the cars are available, verifications can be carried out to a high level of accuracy.

At the same time, now car-making experts can tell, at a glance, potential leakage areas just by looking at the cross sections of the full-scale 3D models of the car. Thus, automobile manufacturers are building their competitive strength by combining in-house expertise with state-of-the-art IT.

Virtual Prototyping

There are many automobile engineers with “skills of master craftsmen” accumulated through years of car-making experience at the prototyping department of Toyota. These experts are said to be able to instantaneously make a baseball glove or a car model one-fifth the size of a normal car, from just one piece of sheet metal.

Today, such car-making experts often apply XVL virtual 3D models in addition to physical car models in pioneering ways in their routine prototyping activities.

One month before building a prototype, they first use XVL to determine if the assembly work is going to be easy and whether standard tools can be used for mounting the engine. They thoroughly check if there are problems beforehand. Just from the overall image and cross section of the car, experts thoroughly familiar with the car-making process can tell if the maintenance of the car will be easy or where water leakage is likely to occur. By applying a cutting-edge technology like XVL, these experts can ensure the quality of the car from an early stage of the manufacturing process.

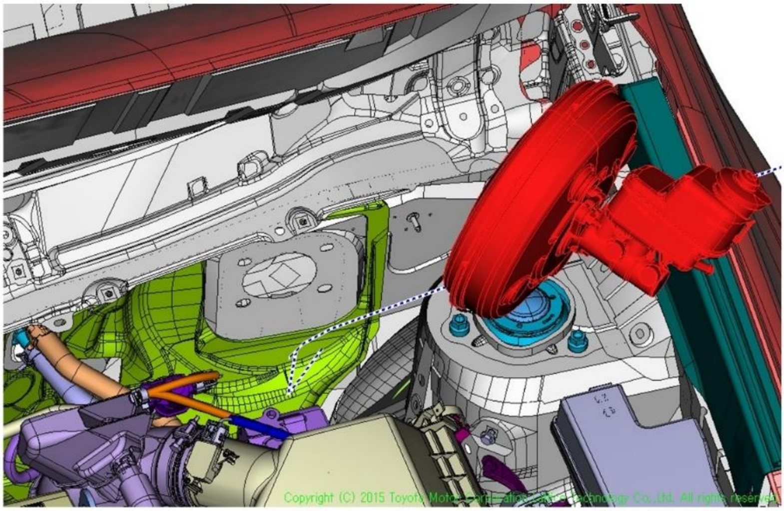
Recently, XVL has also started to play a major role in the verification of maintainability. For example, when repairing a complicated product like cars, it is not easy to intuitively determine whether parts right inside can be removed or not. Normally, car service staff spend endless time and effort to remove surrounding parts one by one to determine if the parts inside can be removed.

The use of XVL can resolve this problem because it automatically calculates whether the concerned part can be removed without interference with surrounding parts. If it is determined that the part can be removed, XVL will even calculate how it should be removed. In this way, XVL enables maintainability to be verified in a short time without having to rely on personnel skills.

Some car manufacturers are also attempting to verify automobile assembly and maintainability using the MR (Mixed Reality) technology discussed in the next chapter. In a head-mounted display, the whole car will appear in front of the wearer’s eyes in the same size and at the same distance as the actual car. As this enables the actual work to be virtually experienced, it is expected to help resolve potential problems in the assembly and maintenance work.

Says Eiji Hikosaka, Manager of the Prototyping Department, “by applying XVL to various prototyping work, we have been able to not only create added value in the prototyping work, but we have also been able to enhance the efficiency of our prototype building work and car evaluation work. XVL has indeed brought significant changes to how we do our work at the prototyping department.” No doubt the collaboration between craftsmanship and IT at Toyota will continue to revolutionize and innovate the company’s manufacturing activities.

Figure 4-3: Serviceability verification at Toyota Motor Corporation.



Source of data: Toyota

Lightweight 3D Solutions (5): Supporting Global Production Using Simple Work Instructions

With many manufacturers establishing their design, production technologies, and manufacturing departments all over the world, the sharing of information between their business bases is crucial for manufacturing high quality products. These manufacturers need to understand the objectives of designs, then think of the appropriate production method and convey the method to the rest of the world. With cultural and language barriers to overcome, what are the ideal means of accurately conveying such information to employees in different countries? They say “a picture is worth a thousand words,” so how many words is an animated 3D model worth?. To beginners or those less trained, animations are probably the most effective means of describing how to assemble products.

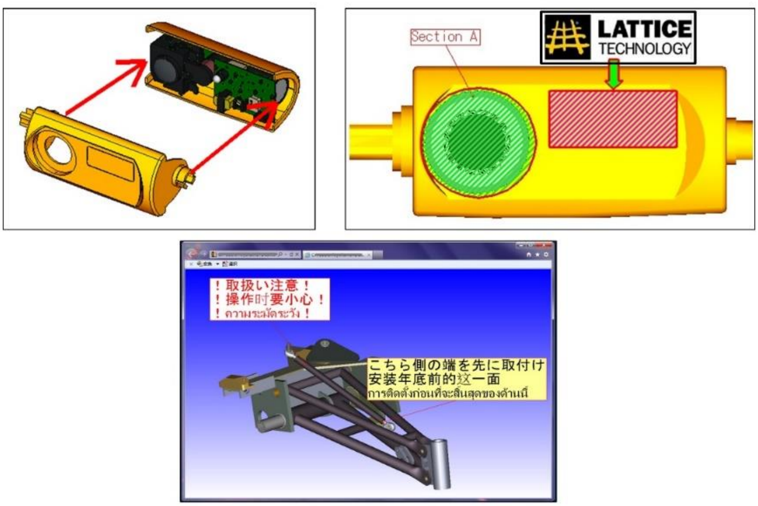
With production facilities all over the world, text based instructions require translation into multiple languages. Moreover, as instructions undergo multiple translations, they can lose clarity and become vague or incomprehensible. This is not an issue with 3D animations as they are easy to understand intuitively, and at the same time, they transcend language and cultural barriers. 3D animations are thus an ideal means of conveying instructions matching the current requirements.

Some work instructions include photos, but this means the actual product is required. By using 3D models instead of the actual product, work instructions can be prepared before the product exists. In fact, adding the assembly process information to the 3D model can enable 3D animated work instructions to be created automatically.

The completed work instructions can be presented in whichever format is required at the manufacturing site, including HTML, PDF, iPad, paper, etc. Images can also be generated automatically from 3D and used for preparing drawings on work instructions.

The figure below shows an example of work instructions prepared from process information and expressed as drawings. 1) The direction for attaching the cap is indicated by arrows, 2) the label position is indicated by hatching, and 3) instructions are shown on 3D models in multiple languages. In this way, information can be conveyed in a very simple manner. Often overseas plants are run by domestic managers working together with local staff. Using such bilingual work instructions will not only ensure that the local staff understands the work involved, but they will also deepen mutual trust relations and engage the staff to improve product quality.

Figure 4-4: Simple 3D work instructions.



Now let's look at how a shipbuilding company uses simple

3D work instructions in their activities.

Use of 3D Work Instructions to Support Global Production at Tsuneishi Shipbuilding

For some time now, manufacturers have adopted the method of building their manufacturing plants in countries with low labor costs or near the site of consumption. Tsuneishi Shipbuilding is one such example. The company built their overseas plant in Cebu Island, Philippines in 1994. In the Philippines where agriculture, forestry, and fisheries are the main industries, only 15% work in the manufacturing industry, and most of the people are unfamiliar with manufacturing work such as shipbuilding. It was thus a major challenge for the company to explain the shipbuilding and assembly processes to the local staff. They found cultural and language barriers to be the greatest hurdle. Most of the local staff did not understand English, making it almost impossible to explain the assembly procedure accurately to them. To overcome this obstacle, Tsuneishi, decided to use XVL to convey work instructions to the staff using 3D data.

Ship builders generally use the block construction method. With this method, instead of building the whole ship at once, the ship is divided into several blocks, and each block is built one by one and then joined at the dock or shipbuilding berth.

Before XVL, this joining process was documented using 2D drawings, block networks showing the block layout, and mounting work tables showing the mounting schedule. However, such 2D information was not able to provide a clear picture of how the completed ship would look. The company, therefore, decided to document the block mounting process using XVL 3D animation.

The XVL 3D animation showed which part of the whole ship was the block currently being made, as well as the deadline. This enabled the manufacturing site to understand construction plans easily, and to plan work smoothly. Tsuneishi also used 3D to document detailed work procedures such as the mounting of hulls and pipes. While it was difficult to explain the mounting procedure only with 2D drawings and words, it could be shown clearly with 3D data.

Being able to check the work involved in 3D before starting the actual work is especially important at overseas production sites where language barriers make communication difficult. Previewing 3D instructions for the local supervisor gives them a clear picture of the process and helps them to understand the precautions to be taken as well as potential problems in the assembly process. Also, the local supervisor will also be able to accurately convey the details of the process to the local staff when teaching them about the procedure. These benefits have made 3D instructions very popular at Tsuneishi.

Teaching local staff members the required work procedure in 3D from an early stage is the same as performing design reviews using 3D models from the viewpoint of the manufacturing site. It allows staff to secure the required workspace and check for problems in the mounting order of parts three-dimensionally. The interactive 3D models are much easier to understand than drawings and allows the stakeholders to more actively participate in review sessions. Problems can be discovered more quickly, and solutions proposed smoothly.

XVL has helped Tsuneishi to discover numerous potential manufacturing issues and proactively correct these problems while still in design. One specific example is known as "hell." Ships are usually built by welding iron plates. However, if the work process is wrong, the shop floor workers can be trapped inside a compartment. Tsuneishi calls these places "hell." Such places can be easily discovered by reviewing the work procedure in 3D from the viewpoint of the manufacturing technician. The figure below shows feedback to designers to open holes for operators to escape.

As seen from Tsuneishi's case, XVL contributes to the "sharing of information across national borders," which is indispensable to today's global manufacturing industry.

Figure 4-5: Reviewing design problems using 3D viewers at the manufacturing site.

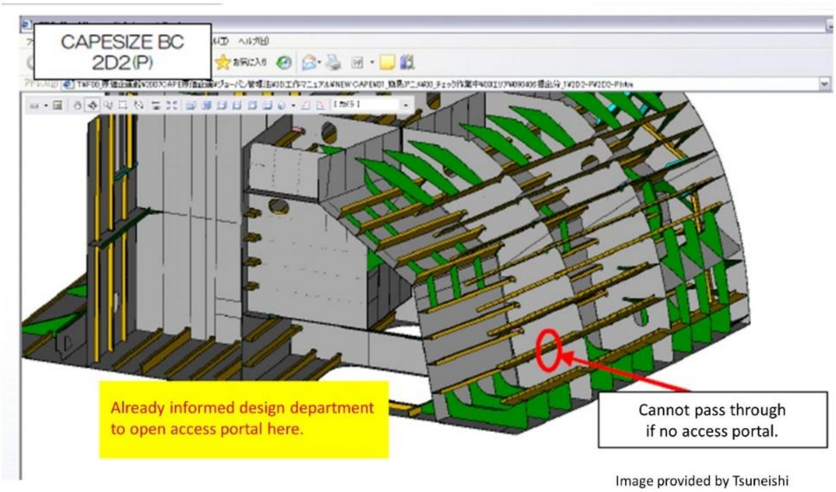


Image provided by Tsuneishi

Reference: "Global Manufacturers /Ideal Process Innovation Development Design Management using 3D and 13 Success Cases" from Nikkei BP Chapter 10 Work Specifications Supporting Global Expansion of Japan

Lightweight 3D Solutions (6): Parts Catalogues Supporting Global Service Networks

Global production and sales are major challenges to manufacturers. However the product maintenance that follows is just as important. Customer reputation has a huge influence on how a product will sell in the future, and building up a lucrative maintenance and servicing business is an important corporate strategy. Parts catalogues support this product maintenance strategy.

Parts catalogues provide information such as product breakdowns, part numbers, drawings, specification, dealer information and more. To expand their business globally, it is crucial for companies to promptly provide easy-to-understand parts catalogues for all products sold overseas. While sales abroad is a challenge to many companies, building a service network can be even harder.

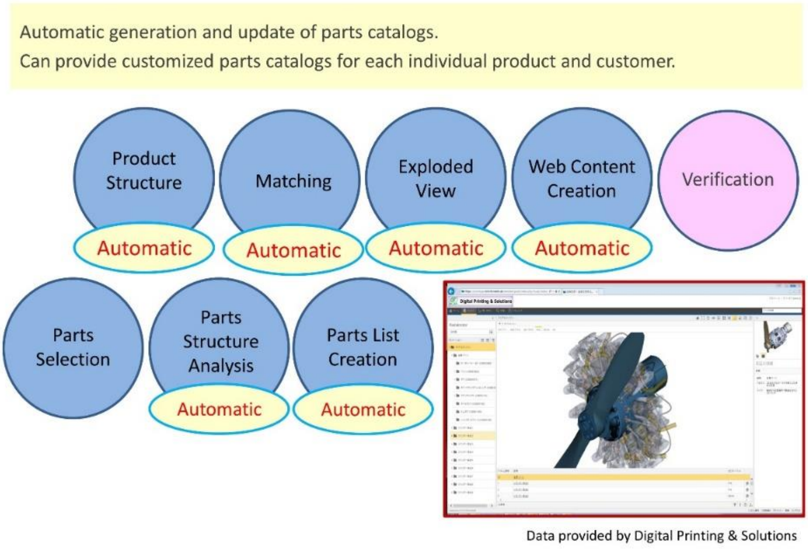
In the past, parts catalogs were often prepared manually. Currently, most global manufacturers prepare and distribute parts catalogs digitally, sometimes over the internet. Now there are solutions that can automatically generate parts catalogs based on XVL models.

XVL models can store all the information required for preparing parts catalogues. Parts catalogues need to provide parts information for each unit to be serviced, and the automatic parts catalogue software can import such information from other systems in the company and display XVL parts for each unit.

Attribute information such as parts suppliers and costs can also be imported directly into XVL models. By importing all the information required for the parts catalogue to XVL, the parts catalogue can automatically be generated from XVL. For instance, drawings in the parts catalogue can also be generated from 3D models, and the names of these parts can automatically be matched with the drawings.

Automatic generation of parts catalogs is faster, less expensive and more accurate than manual compilation methods. Moreover, automatic generation of parts catalogues allows manufacturers to prepare parts catalogues of various products customized to each customer. As shown in the next figure, solutions realizing this are already available. This may well be an IT approach that can support the mass customization aimed by Industrie 4.0.

Figure 4-6: CATALOGCreator: a solution for creating parts catalogs using PLM information.



Semi-Automatic Creation of Parts Catalogues at Hitachi Construction Machinery

Hitachi Construction Machinery has been creating various documents using 3D, prompted by the rapid increase in manufacturing models. Since 2000, construction machines have been in enormous demand due to the remarkable growth of emerging nations such as China, India, Brazil, etc., leading Hitachi Construction Machinery to expand and diversify their product line.

To handle this kind of global increase in demand for construction machines, companies need to innovate not only their production systems but also their methods of preparing parts catalogues, instruction manuals, service manuals and other technical documentation.

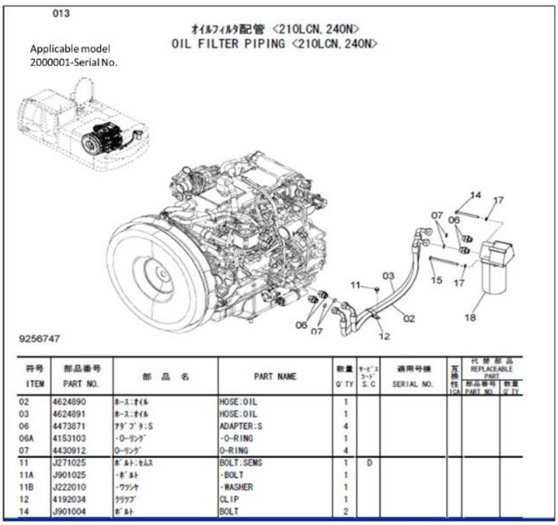
Hitachi Construction Machinery had been using CAD to prepare their parts catalogues, but they were facing considerable limitations due to the massive data volume of complicated construction machinery. The company thus decided to use an XVL-based software which can handle lightweight 3D data. Per Kiyohiki Otani, an engineer working at the company's Technical Information Center, if we had not started using this new system, we would not have been able to cope with the growing number of models.

Today, the company designs small and medium construction machinery -- cranes, mini shovels, etc. -- in 3D. All the parts catalogs are produced using XVL. The company also uses XVL to create manual instruction drawings and prepare sales promotion material.
However, the company makes it a rule to distribute parts catalogues on paper. Every piece of construction machinery

comes with a parts catalogue. However, even with paper delivery, using XVL to produce parts catalogs is much more efficient than using CAD. Compared to before XVL was used, parts catalogues can be made in 20% shorter time and with half the costs.

The company generates more than 200 types of parts catalogue every year. With the XVL-based software, they have been able to cut costs by several hundred thousand dollars a year -- saving money and growing their global business.

Figure 4-7: Parts Catalog created using 3D at Hitachi Construction Machinery.



符号 ITEM	部品番号 PART NO.	部品名	PART NAME	数量 Q'TY	ｻｰﾋﾞｽｺｰﾄﾞ S.C	適用号機 SERIAL NO.	互換性 ICA	代替部品 REPLACEABLE PART 部品番号 PART NO.	数量 Q'TY
02	4624890	ﾎｰｽ:ｵｲﾙ	HOSE:OIL	1					
03	4624891	ﾎｰｽ:ｵｲﾙ	HOSE:OIL	1					
06	4473871	ｱﾀﾞﾌﾟﾀ:S	ADAPTER:S	4					
06A	4153103	-Oﾘﾝｸﾞ	-O-RING	1					
07	4430912	Oﾘﾝｸﾞ	O-RING	4					
11	J271025	ﾎﾞﾙﾄ:ｾﾑｽ	BOLT:SEMS	1	D				
11A	J901025	-ﾎﾞﾙﾄ	-BOLT	1					
11B	J222010	-ﾜｯｼｬ	-WASHER	1					
12	4192034	ｸﾘｯﾌﾟ	CLIP	1					
14	J901004	ﾎﾞﾙﾄ	BOLT	2					

Data provided by Hitachi Construction Machinery

Reference
3D Digital Document Innovation for Effective Results!
Use of 3D Data XVL: Chapter 10 Revolutionizing the Documentation Process Using 3D at Hitachi Construction Machinery
Published by JIPM Solution

Lightweight 3D Solutions (7): Innovating the Technical Illustration Process

The greatest means for a manufacturer to differentiate itself from others lies in providing products to customers when the customers need them. Customers will buy products available now, even if they cost more than other products available later. A product today has more value than a product provided one week later. When delivering products on short deadlines, rapid generation of technical documents like instruction manuals and owner’s manuals are necessary. Products cannot be shipped without these documents. When preparing these documents, the most time-consuming and costly task is preparing the drawings.

Technical illustrations are crucial for explaining products in instruction manuals and service manuals. Normally, illustrations are drawn after the prototype has been completed by disassembling the actual machine and sketching the parts or taking photos with a digital camera and tracing the photos. This means that illustrations cannot be prepared until the actual machine is ready. Also, it costly and time consuming to prepare illustrations manually.

These problems can be resolved for products which have been designed in 3D. Using 3D models, illustrations can be prepared quickly and efficiently. Because technical illustrations are generally drawn according to mathematical rules, they can automatically be calculated from 3D models. The use of 3D models, therefore, enables instruction manuals and service manuals to be completed much more quickly.

Documents are often prepared jointly by the manufacturer providing the instruction manual and the service provider compiling the document. Lately, the common format used by the two sides is increasingly becoming XVL, and use of lightweight XVL for illustration work is proving to be of great benefit to both the manufacturer and service provider.

There is a phrase in economics called “network externality.” It means that if many people around us have the same product, the value of our product will increase. A typical example is a telephone. If there are only two telephones, we can only talk to one person. However, if many people around us have telephones, we can talk to anyone.

In the world of technical manual illustration-making, this network externality is gradually emerging. With many manufacturers using XVL today, service providers can expand their business if they have the skills to create illustrations from XVL in Japan.

Enhancing Illustration Work Efficiency at Casio

Manufacturers like Casio started using 3D data to create illustrations from the early 2000’s. The company started using 3D CAD from the beginning of the 90’s, and once they had accumulated sufficient data, the embarked on the use of 3D data from 2002.

Their goal was to increase efficiency using 3D data in the areas of design, quality, mold, and materials. As part of this, they decided to use 3D CAD data created by their design department to prepare manuals, and named such manuals “e-manuals.”

In this e-manual project, CAD models still in the midst of being designed were used for creating the illustrations inserted in the manuals to speed up operations. By using models before their design was approved, Casio was able to accelerate the manual completion time, and thus shorten the product development time.

In the beginning, the company attempted to use the CAD data for preparing the manuals but found that processing the huge files took a long time. It also took a long time to send the CAD data to their partner documentation company. To resolve this, they used lightweight 3D XVL data and successfully shortened data transfer time. The illustration work at their partner document company also became easier. Moreover, the XVL solution proved to have faster conversion times and better illustration generation tools, allowing the company to complete illustrations quickly and easily. The figure below shows a sample of an instruction manual of a digital camera created from XVL.

In this way, use of XVL enabled the company to sharply reduce the illustration generation time, and save tens of thousands of dollars a year. Beyond the cost savings, there were also several other benefits. Here are some comments from those involved with illustration work at the company.

- “We have been able to shorten delivery time by starting illustration work from an early stage using data of the product still in the process of being designed.”
- “We have been able to prevent errors in manuals since we can directly refer to product shape and assembly structure information.”
- “We have been able to reduce inquiries made to the design department when preparing the manuals.”
- “We have been able to more or less eliminate the assembly work of sample products required for preparing manuals.”
- “The transportation of large objects such as musical instruments and printers used to be very inefficient, but we no longer need to move large items such as musical

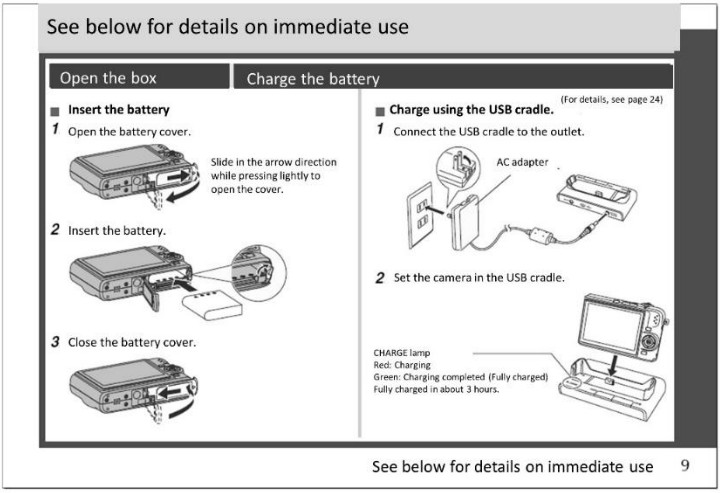
instruments.”

Designers also appreciated the fact that the illustrators were making fewer inquiries to the design department, especially during the busy time just before product release.

The e-manual project started in 2002 and expanded to 12 products such as digital cameras and musical instruments in just the first year. As the effectiveness of the e-manual project became more clear, its scope further widened. Moreover, the use of 3D data for creating manuals also helped increase illustration quality and clarity -- benefits that were highly appreciated by the users reading the manuals.

Now it is common practice to use 3D data for preparing the illustrations in manuals. The frontloading of manual preparation is a key technique for shortening product delivery time.

Figure 4-8. Instruction Manual created using 3D at Casio.



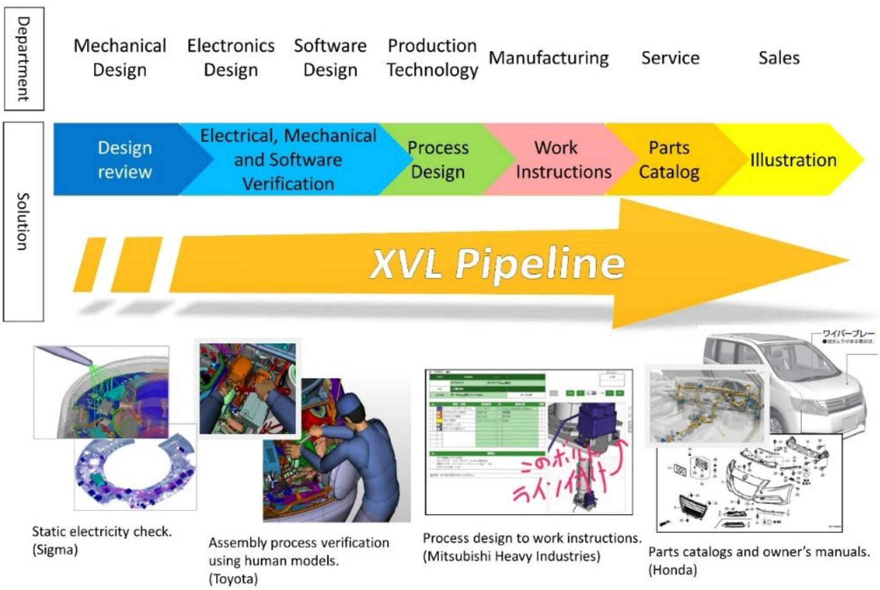
Reference
3D Manufacturing Innovation
How Digital Data will Change the Japanese Manufacturing Industry
Chapter 10 Casio: Creating Manuals using 3D Data

As discussed in this chapter, lightweight 3D models can improve business activities in various departments in the manufacturing industry. The examples clearly show how PLM improves quality, accelerates delivery time, and reduces costs in such areas as design, production, facility development, prototyping, plant, sales preparations, and services.

As lightweight 3D data becomes available to the various departments, it circulates throughout the company. We call this the "XVL Pipeline," through which information flows from the design department to the rest of the company. The next figure illustrates the XVL Pipeline and users implementing individual solutions.

If only of the departments of a company starts using XVL to optimize its processes, it will increase local efficiency, but the company will miss out on the benefits that XVL could bring to other departments. However, when the XVL pipeline is established, it makes the data available to all departments, often enabling unexpected efficiencies and eventually total optimization.

Figure 4-9: XVL Pipeline enabling use of PLM information throughout the company.



XVL has been likened to traditional oriental medicine. It gradually penetrates each department and improves the corporate culture. Eventually, companies installing the XVL pipeline will be able to achieve a very strong corporate culture.

Chapter 5: Winning Global Competitions with Constant Improvement

Roles of 3D Data in the Future

The technological innovation of IT related hardware and software continue to accelerate. New technologies that will change our lives -- self-driving cars, drone delivery services, etc. -- are being developed today. Innovation and evolution are taking place across industries, for instance, improved sensor technology, big data processing, and deep learning AI.

This chapter introduces some cutting-edge 3D technologies and their latest applications, focusing on the following four topics.

1) Development of 3D information using tablets, especially iPad.
2) Use 3D point cloud scans of existing facilities
3) MR verification of human models and 3D models
4) Fusion of reality and virtual

Note that (2) to (4) are the further expansion of the “CAD+1” concept -- enhanced 3D models that replace prototypes.

Trailblazing companies are attempting solutions which combine these new technologies and XVL, and some have started to achieve success. Efforts like these, which push the envelope, are critical for achieving the maximum value of PLM data throughout the enterprise.

The end of this chapter will introduce some ideas on how organizations can prepare to effectively use PLM and lightweight 3D data to compete and win in the global marketplace.

Next-Generation 3D (1): Tablet-based 3D Information

With the advent of lightweight 3D, it is an increasingly common practice to bring laptops to the manufacturing site to check work procedures in 3D. Placing desktop PCs at the manufacturing site can be a hassle: keyboards and power cables take up space and mouse operations can be troublesome. The result is that at most plants, employees must travel all the way to the PC rooms inside the plant to check 3D data or bring paper drawings to the shop floor. This is bothersome and a waste of time.

The emergence of tablets has changed this situation. Tablets such as the iPad are easy to carry around and to use. We have entered an era where people now bring 3D data to the manufacturing site, instead of drawings. This trend is even more accelerated by the presence of free viewer "iXVL Player" which can display dimensions and annotations on the 3D models on the iPad.

Tsubamex is a pioneering company that uses the iPad in its manufacturing process. The company was featured in an article "Factory Revolution" in the Nikkei Newspaper. At Tsubamex's plant, employees using XVL on their iPads housed in special Tsubamex metal cases are an impressive sight. So, what changes have such browsing of 3D data on iPads brought about?

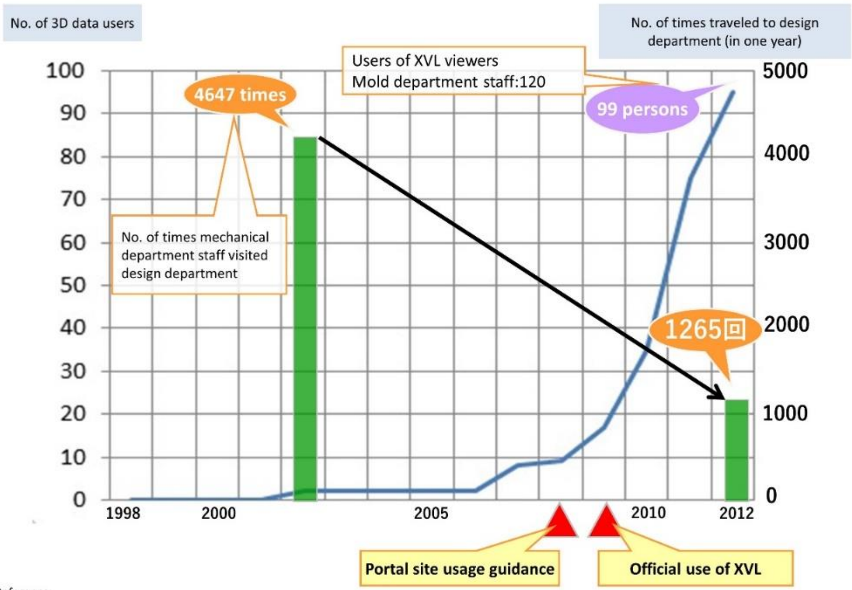
Factory iPad Revolution at Tsubamex

Tsubamex is enhancing their productivity by providing an environment for all employees to easily access 3D data at the workplace. Based in Niigata Prefecture, the company manufactures molds for automobiles and home appliances. Aiming to complete the manufacturing process from mold design to the first press in just one month, the company enthusiastically and aggressively optimizes the mold manufacturing process with strategic IT investments. Their goal is to shorten delivery by designing all molds using 3D data and maximizing the use of 3D in all processes. The graph below shows the number of users of 3D data at Tsubamex. The number continues to increase, and now 99 out of 120 employees, which is 80% of all employees, use 3D data in their work. So how did the company accomplish this? The two key factors were “setting up a portal site which uniformly manages mold information” and “incorporating lightweight 3D data XVL in the manufacturing scene”.

In 1982, the company started using Dassault Systèmes’ 3D CAD software “CATIA,” becoming one of the earliest users of the software in Japan. By 1998, they had started designing all their molds using solid models. They were quick to apply XVL at their manufacturing site as well. Starting use in 2007, by 2009 Tsubamex was officially using XVL in all their manufacturing processes. By 2010, the company was also using XVL for design reviews. More recently, their finishing department, which is more oriented towards handwork and therefore not used to PCs, started using iPads.

XVL data is automatically generated from CAD data, then linked to production management information, and automatically converted to formats which can be displayed on the iPad. Information which used to be just on paper drawings can now be displayed as 3D information on the iPad and compared to the actual product on the shop floor. The iPads link to the portal site and can quickly download 3D models, notes, and all other related information. Now engineering staff can check the dimensions of 3D models on the iPad and hold troubleshooting meetings with the manufacturing site staff, etc. using abundant information related to the 3D models. In this way, information serves as the most effective solution at the workplace.

Figure 5-1 Effects of adopting XVL for manufacturing.

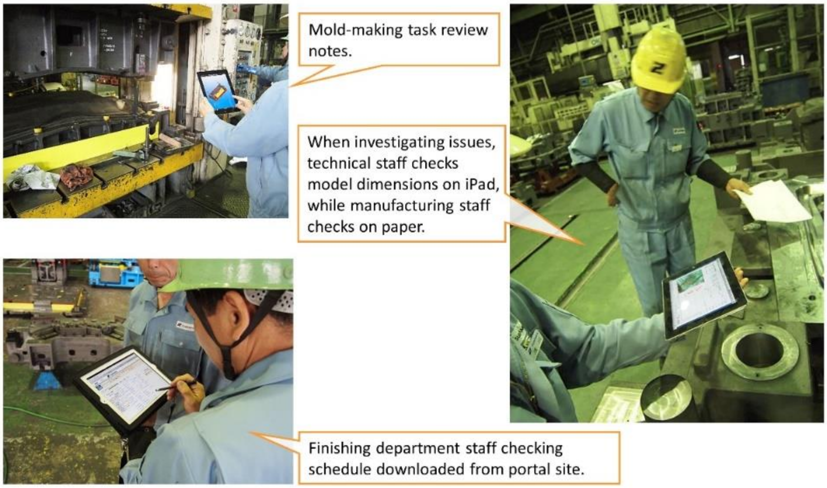


Reference
Nikkei Technology online column "3D Data Process Revolution for Global Manufacturing"
31st: Case study of Tsubamex, challenging ultra-short mold making and delivery using 3D data

Data provided by Tsubamex

Tsubamex has transformed their manufacturing process from being based on drawings to being based on 3D models by accumulating successful experiences on the shop floor. Moreover, as XVL use increases, inquiries from the manufacturing department to the designers have decreased. The abundance of available information enables both parties to communicate much better, leading to dramatically shorter delivery times.

Figure 5-2: Manufacturing procedures using iPad and XVL on the factory floor.



Reference
Nikkei Technology online column "3D Data Process Revolution for Global Manufacturing"
31st: Case study of Tsubamex, challenging ultra-short mold making and delivery using 3D data

Photo provided by Tsubamex

Next-Generation 3D (2): 3D Point Cloud Scans of Existing Facilities

In the manufacturing industry, topmost priority is always given to the manufacturing site and products being manufactured. Whenever quality problems occur, first, the manufacturing site and product manufactured are investigated to identify the cause. Investigating both carefully are important, but the use of digital technologies to determine the root of problems can accelerate various processes.

Things would be much easier if 3D CAD data were available for everything. However, when plant buildings and facilities are updated, their drawings are usually not revised, resulting in differences between the two. On the other hand, even if the drawings were revised, in most cases there are changes between "as designed" and "as built."

For example, when installing a new power generator in an old plant, various issues need to be considered. Given that the old plant will already have facilities, some of these may need to be removed or relocated to accommodate the new power generator. If the power generator is large, it may need to be disassembled into pieces to be loaded into the plant. If the plant drawings are out of date, then it will be necessary to measure the site to make sure that the parts can be brought inside. Also, some plants can be dangerous, and safety precautions are required. Moreover, all of these issues are magnified for remote plants that are expensive and time-consuming to access.

In such cases, one solution is to measure the plant with a laser scanner and use XVL combine the point cloud data of the plant with a model of the generator.

Scanning Existing Facilities and Reviewing Point Cloud Data

Current laser scanners can scan 360 degrees up to several hundred meters away. One scan can acquire thousands of 3D points. However, one scan will not be able to measure places which are out of view, so there is a need to measure several places to obtain a set of point cloud data. By synthesizing these multiple point cloud data, even large buildings such as plants can be reproduced as huge 3D point clouds.

The XVL point cloud solution developed with Elysium comes with functions for synthesizing multiple sets of point cloud data automatically and for removing noise generated during

scanning.
For example, if the scans capture operators who are moving around in the plant, they are automatically determined to be noise and can be separated from the data. In this way, point cloud data for accurately reproducing the plant and facilities can be acquired.

Contemporary power generators are usually designed using 3D CAD. This data is converted to an XVL model and integrated with the point cloud data. This enables the user to check the installation and make sure that the equipment will fit in the space. With the XVL point cloud solution, the user can observe the virtual plant from any angle, can measure the distances between the models and the point cloud data and view cross-sections of the integrated scene. In other words, the user can easily check whether the power generator will fit as planned.

The integrated scene can be shared by all affected parties. This enables smooth communication between the plant staff, power generator manufacturer, and installation company. Also, it prevents unforeseen problems that may occur after completion. With virtual plants on the screen, any part can be viewed and from any angle. You can even remove the roof or look up through the floor. Viewing from unusual perspectives can show unexpected details and prevent unanticipated problems.

Safety is a top priority in manufacturing. However, if an accident does occur, 3D digital models can help diagnose the situation. Everyone can review the digital model, and can record lessons learned to help prevent future accidents.

Verifying and Upgrading Industrial Infrastructures

The XVL point cloud solution is useful for the long-term verifications of infrastructures such as plants, buildings, ships, etc. as well as verifications of upgrades of company facilities. In practice, facilities are not replaced; they are upgraded as required for of safety and efficiency. Let's look at two simple examples.

(1) Take for example building elevators. They are replaced with new elevators when their service life ends, to meet new safety requirements, and to respond to new social needs such as handicap access, etc. In this case, the old elevator and surrounding areas can be scanned, and the points representing the old elevator can be deleted. Next, an XVL model of the new elevator can be inserted into the scene to check for interferences and validate the installation procedure. Performing these prior digital verifications can prevent unforeseen installation problems.

(2) Ships have long service lives. In most cases, the body of an existing ship is reused and upgraded with new facilities. One example is cargo ships. In the case of cargo ships, after the cargo is loaded, the ballast tank is filled with seawater to maintain the ship's balance. At the destination, the ballast water is drained out. This can introduce exotic marine organisms and cause environmental problems. To address this problem, ships are now required by law to install ballast water treatment systems. When installing such new systems on existing ships, it is critical that they do not interference with existing pipes. The XVL point cloud solution can verify that this is the case.

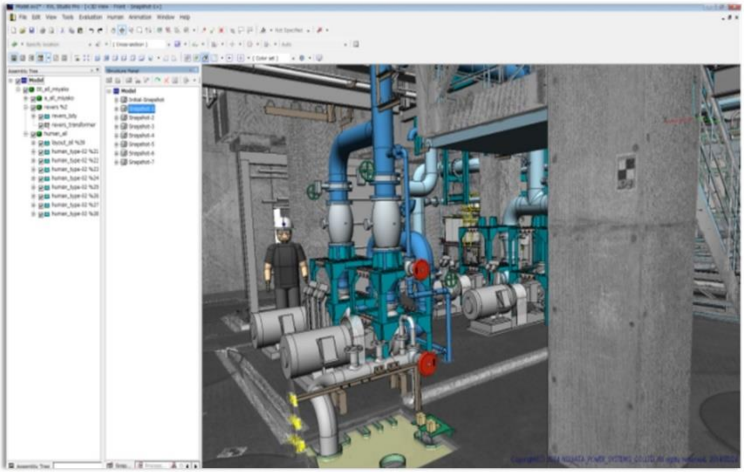
Verification of Plant Construction Procedures at Niigata Power Systems

Niigata Power Systems is a machine manufacturer boasting a large market presence in diesel engines for ship or power generation, gas engines and gas turbines. The company was quick to apply 3D CAD to their design activities, as well as convert the 3D design data to XVL, and use the data in various departments to implement many business optimizations. For example, they use the XVL point solution to integrate large 3D models with very large point clouds.

Today Niigata Power Systems is using this solution to design large plants. Before, whenever they wanted to install new equipment in existing buildings, they could only conduct reviews using the drawings of the buildings. Given that most buildings undergo renovations that reconfigure structural elements like pillars, the drawings were often out of date. Due to such discrepancies, it was not uncommon that new equipment would not fit the buildings.

Faced with this problem, the company wanted a digital modeling technique that could measure the current state of buildings and display it as a 3D point cloud. With the XVL point cloud solution, they could visualize the point cloud data, add the XVL model of the equipment to be installed and validate that it would fit in the existing space. The following illustration shows the integration of point cloud data and 3D models.

Figure 5-3: Using XVL to integrate large 3D models with massive point cloud data.



Data provided by Niigata Power Systems

Here is what Niigata Power Systems Technical Center Plant Engineering Group Construction and Design Team Senior Assistant Manager *Toshihiko Fukuoka* says:

> "The combined use of 3D models and measured 3D points group data is very useful for checking interferences and reviewing the installation procedure for installing our products in customers' buildings. We have been requesting a software with such functions for a long time, and now, at last, our wish has come true. Because of implementing this solution, we are now able to see things which were hidden in drawings and at the manufacturing site until now. For instance, by observing the integrated model from various angles, we can now see the manufacturing sites from a bird's eye view. With digital models, the roofs of plant

> buildings can be easily removed, and the installed state of equipment in the plant can be checked. This means that the installation procedure can be planned by cross checking the current state of the manufacturing site and design models. Using infrastructures efficiently through maintenance are growing increasingly important to build a sustainable community. The new solutions introduced here thus realize such a society and will play even more important roles in the future."

Next-Generation 3D (3): Mixed Reality

Creating a clear process that can be accomplished without stress is very important for improving the quality and efficiency of manufacturing as well as maintaining employee morale. XVL has a solution that uses human body models, tools and products to verify the ease of assembly processes. The human model is posed in the work posture, and a tool is placed in the human model's hand, and the viewpoint is fixed to the tip of the tool. Next, the tool is moved per the work procedure to check if the posture is comfortable and if the tool and surroundings can be seen clearly. As the body follows the process, the screen shows what can be seen in real time.

By preparing small, medium, and large human body models, workability can be checked for people who are tall, of average height, and who are short. Such human body models are used to verify the workability of processes for mass producing expensive products like cars. However, this problem has one drawback - it can take considerable time to define detailed postures for human body models.

What is needed is an approach which allows engineers to experience a work process more easily. The answer to this is a solution that integrates Canon's Mixed Reality technology MREAL with XVL.

Experiencing Assembly Work Using Virtual Models

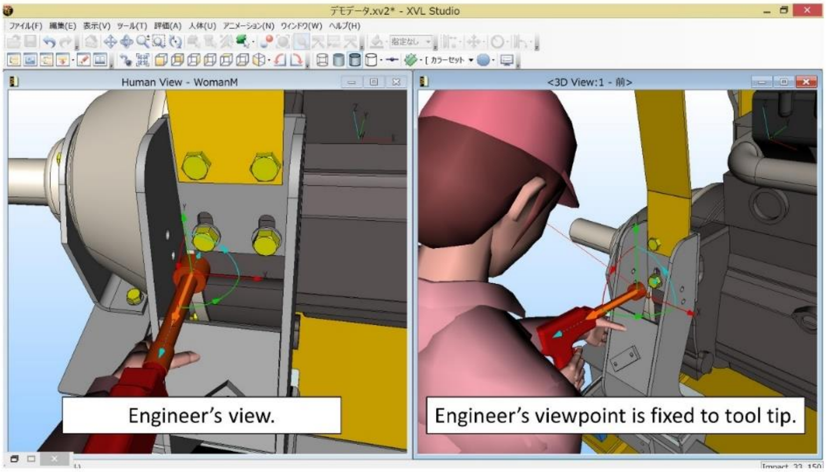
Mixed reality (MR), also called augmented reality (AR), is a technology the inserts computer graphics models of virtual objects and data into real scenes.

By combining MR and XVL, cars and buildings which have been fully assembled in virtual space can be reproduced at full scale. Moreover, engineers can experience the objects with their body through simulation, allowing them to discover manufacturing and assembly problems and resolve them.

When the visor-like head-mounted display is worn, the car in front appears at full scale. Since tools can be "brought into" this virtual world, this allows the engineers to experience and check ease of maintenance, etc. using real tools. Interferences between the actual tool and virtual parts are highlighted in color to alert the user about potential conflicts so that they can fix the problems.

The addition of XVL assembly process information to this solution provides even more benefits. Since the manufacturing process can be reproduced step-by-step, engineers can check each step using MR, focusing especially on areas of concern. They can also virtually use tools to verify if they can smoothly attach actual parts. This ability to verify that the tool used in the manufacturing process will fit a part or validate that a certain posture is comfortable by moving the body in the virtual world is a significant benefit of MR. At the same time, the ability to record issues as 3D data and send this data accurately to related departments is a significant benefit of XVL.

Figure 5-4: Verification of workability using human body models.



When the tool moves, the engineer's viewpoint and field of view follow.

Using MR with digital mockups enables assembly and service engineers to test the ease and workability of the processes before the actual manufacturing machines are installed, thus front-loading this important manufacturing step.

Figure 5-5: Experiencing the future using mixed reality and XVL.

In the mixed reality (MR) environment, one can interact with full-scale virtual models.

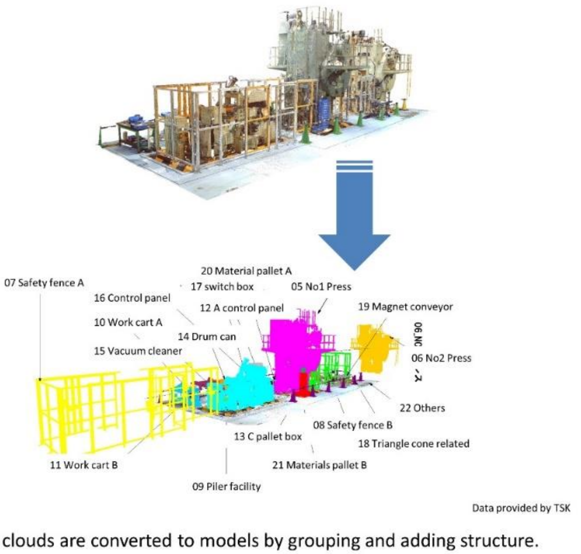
Next Generation 3D (4): Digital Collaboration with Measured and Designed Data

This chapter has introduced two methods of integrating the virtual with the real: point cloud and mixed reality. It is possible to further integrate the virtual with the real and collaborate in that environment over the internet.

However, one challenge to this is the large size of the point cloud data. Point cloud data can be tens of GB -- much too large to be sent over the internet. The latest version of XVL solves this problem. Point cloud data is unstructured -- it is one big clump. XVL adds structure to the cloud data and turns it into a point cloud model.

So how can point cloud data be converted into models? The answer is by applying the same structure that is found in CAD models – parts, modules, assemblies, etc. Applying these structures to point cloud data enables the system to interact with individual parts of the cloud. For example, parts of the cloud can be moved or deleted. Their movements can be used to create animations. One application is to create models of the point clouds of actual plant facilities. Then procedures can be animated on the point cloud models to identify problems. This means that the manufacturing site and manufactured products can be digitally verified without the need to create CAD models.

Figure 5-6: Creating point cloud models by grouping and structuring point cloud data.



Points clouds are converted to models by grouping and adding structure.
Point cloud models can be disassembled by region and each region can be named.

Another approach to reducing the point cloud data size is to extract only the point cloud of problem areas. By reducing data volume, the point cloud data be stored in XVL files. Furthermore, converting point cloud data to XVL models enables anyone to view it using the free viewer. Point cloud models can also be displayed together with 3D models. Once they are combined, they can be used for manufacturing collaborations. Discoveries made by overlapping the scanned data and design models can be shared with all those involved.

What about when point cloud data is integrated with MR? MR systems can display CAD models of future designs together with point cloud models of the current manufacturing site in actual size. What's more, this data can be cross-checked with past facility plans, etc. to see how present facilities have been improved, how they can be relocated to future plants, and more. This is the ultimate front loading world enabled by "CAD+1".

Future Facility Design at TSK

Together with Lattice Technology, TSK developed a novel verifying solution by integrating the past, present, and future facilities, and is applying this solution to their manufacturing activities.

TSK, a subsidiary of leading automobile parts manufacturer Taiho Kogyo, has strongly focused on "measuring products in their full size" to maintain the high QCD (Quality, Cost, and Delivery) level of all their products.

Recently, large improvements in the accuracy of measurement devices have allowed more companies in more industries to apply measurement technologies. Already many manufacturing companies are achieving successful results at their production sites.

Per Hideki Takeda of TSK's QA Department, the significance of using 3D scans is as follows:

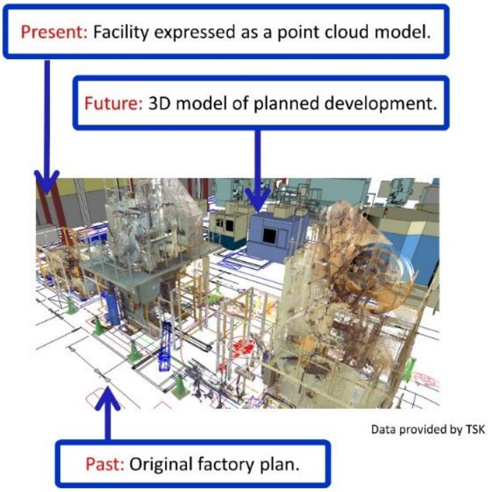
> "By appropriately processing measurement and analytical data obtained using 3D scan and feeding this back to the 3D CAD or XVL environment of QA or design & development departments, the information can be used for various purposes such as evaluating the quality and checking assembly. Even reverse engineering based on actual products can be achieved with high accuracy."

As shown below, the latest solutions enable point cloud models of current facilities to be positioned over 2D drawing data of past configurations, to compare both and consider future plant design modifications.

In the figure, the future plant is displayed in XVL format converted from CAD data. From this model, it can be digitally verified how present facilities will be relocated to new plants, and so on.

Recently, TSK has also tried to design future facilities by comparing old factory drawings with the point cloud models of present facilities in virtual space. By virtually investigating problems, which until now could only be checked on site, they hope to prevent rework and shorten development time. Through these efforts, TSK is attempting the "ultimate facility design."

Figure 5-7: Looking back at the past to evaluate the present and future.



Showing the past, present, and future by integrating point cloud data, drawing data, and 3D models.

Next Generation 3D (5): 3D Printers

3D printers have drawn enormous attention and interest. Although they have been in development for decades, it was the release in 2012 of Chris Anderson's book "MAKERS" that ignited this "maker's boom." With a 3D printer and an internet connection, now literally anybody can be a manufacturer and sell his/her products to the world.

3D printers have become a popular tool for building prototypes. There are even whole prototype automobiles made by 3D printers. However, it seems the initial boom of people seeing 3D printers as a magic box has ended, as clearly seen by the drop in the stock price of largest 3D printer manufacturer 3D Systems from close to US$100 in 2013, to below US$15 in 2016.

3D printers are still quite limited in that they can only build products with limited materials; costs are high, and so forth. When it comes to large, expensive products like cars, it can cost several hundred million dollars to make just the main body resulting from tooling and setup costs. 3D printers can make actual products easily. So, it is still possible that they will one day become an important tool for mass customization.

For the time being, digital mockup techniques like XVL and 3D printers will coexist and be used for manufacturing. If products are designed in 3D, they can be verified using XVL solutions as well as built using 3D printers immediately. The expectation is that digital XVL models, which are more efficient and convenient than prototypes will be used as much as possible to check a product being manufactured, and only when there is need to touch the actual product, then 3D printers will be used to fabricate the product.

To date, the greatest obstacle to the use of 3D printers by general consumers is that they need to prepare the 3D data themselves. Now, XVL data is common and increasingly being used for furniture, plumbing fixtures, and electrical parts. Eventually, XVL may be more commonly used for consumer products as well. The use of XVL data for 3D printers is expected to grow even more given the convenience that XVL data can be output directly to 3D printers. This may open paths to new applications of 3D printers, and subsequently, new business models will be born.

Three Important Points in the Use of 3D Data

Chapters 4 and 5 introduced cutting edge techniques for using 3D data, with examples of companies applying such data in their business activities. To follow up, here are three key points for company managers that are interested in applying 3D data to improve their business processes.

(1) Leadership

Whether in the manufacturing sector or IT sector, born leaders have the belief that improvements can be made and the will to make them. It is vital to the success of reform efforts to find and foster such human resources. Most of us are comfortable with how we do our work now and are reluctant to make changes. The adoption of new technologies also means risks must be taken. The key to the success of a company is finding “process innovators,” people who are not afraid of taking such risks, people who can tirelessly explain to and convince their colleagues and peers of innovative ideas, and people who challenge their work passionately filled with excitement and hopes in the potentials for infinite success of new technologies.

(2) Teamwork

In economics, there is a law called the Pareto principle which states that, for many events, roughly 80% of the effects come from 20% of the causes. According to this law, only about 20% of all employees are the ones who are producing the results for their company. When attempts are made to use PLM data on a company-wide scale, it will involve many departments such as design, production technology, prototype, service, IT, etc. For PLM to be successfully used, it is necessary to form a team of the best people from the top 20% most competent personnel of each department and have this 20% start blazing the path. This is because once this team that will build the company’s future starts running, most of the remaining employees will follow. If this team can reform processes at the manufacturing site for everyone at the site, the new business processes will eventually take root.

(3) Top down
Most manufacturers are already using 3D CAD/PLM systems for their design activities. We are now in an age where design assets can be used as assets of the whole company. In such times, management must indicate clearly what the company's objectives are, for example giving top priority in reducing delivery times, etc. It is vital that they then select leaders of process innovation for using the PLM data and teams to support these leaders, and continue to motivate them to attain their goals by rewarding achievements, etc. Such efforts to change the workplace usually take years. However, once a company succeeds in something, success can be built up rapidly by expanding that first success horizontally to other departments.

Winning in the Age of IoT Requires Sophisticated Processes

For PLM data to be used daily by the whole company, it is important for the manufacturing department to play the lead role. In one company, the manufacturing workers originally hated IT but became 3D evangelists after they saw how convenient it was for them to obtain clear product views by pasting 3D views on paper. Other companies have successfully implemented 3D design reviews with large numbers of employees by setting up such large screens at multiple locations inside the company. These examples show that everyone will work on improvements if they know that the improvements will make their workload lighter and if the improvement activities are fun for them.

It is more challenging to using 3D data throughout the organization when not all of the design data is in 3D. Consider a company that does only 70% of their design in 3D. In that case, there will be two types of people: those who think “we only have 70% 3D data” and those who think “we already have 70% 3D data.” Experience shows the latter group will succeed and they will succeed fast. This is because if 70% 3D data is found to be useful for creating illustrations or verifying work processes, the manufacturing department will, without a doubt, urge the design department to incorporate even more 3D design. Once PLM data accumulates and the effectiveness of 3D data is understood, even more, demands for 3D designs will also further increase. Subsequently, 3D design accelerates, the results of using 3D data increase, and eventually, the company-wide use of PLM data is achieved.

In this way, PLM information will flow through all the “XVL pipelines” of the company. Then, each department can turn on the tap and extract XVL models for their own use. This is the “One file PLM” concept. PLM data, which was originally an asset of design departments, becomes a company-wide asset that enables major cost improvements. Through this “CAD+1” solution which replaces prototypes, shorter delivery times and further quality improvements can be realized.

Soon, we will see the birth of the best business processes that meet the global needs of the organization, and these processes will indeed be the perfect processes for surviving in the age of IoT.

Conclusion

Presently, the global manufacturing industry is undergoing a revolution based on IoT. For instance, Germany's Industrie 4.0 strategy aims at two types of integration: the integration of virtual and reality, and the integration of PLM (Product Lifecycle Management) and FA (Factory Automation).

As discussed earlier in this book, the concept of "CAD+1" aims to build 3D models that are better than actual machines, and realize concepts that merge virtual and reality.

This book has explained that by converting PLM information, which is the design assets of the design department, into lightweight XVL 3D information, this design asset can be shared downstream. If this can be realized, it would then be possible to integrate design assets with information obtained through IoT such as operating state of facilities and parts quality provided by plants. This integration of information will no doubt serve as a powerful driving force supporting the integration of PLM and FA.

By integrating upstream design information with lightweight 3D information, the information can be shared with later processes as well as with related departments, allowing those departments to make use of the information in their work in the best way. By creating a consistent flow of information using XVL, all these departments from design to production technology, prototyping, service, etc. can effectively use the design assets to optimize their respective tasks, which eventually leads to overall optimization. This book has introduced many success cases of pioneer users of XVL.

To conclude, please let me introduce the story of a chess champion. I am sure many are familiar with the name Deep Blue, the name given to a supercomputer developed by IBM for playing chess, which beat top world chess player Garry Kasparov in 1997. At that time, the computer's victory against the world champion made headlines around the world. So, who is the current champion?

Today, chess tournaments are fought between computer and humans. Recently, there was a story of how two amateur players used computers to thoroughly study the strategies for beating computer opponents and succeeded in beating a computer chess champion.

What lesson can we take from this? It shows that by combining good processes with good IT approaches, even a small manufacturing company can compete and succeed against the best in the world.

To learn more about how to leverage your 3D design data downstream to departments such as manufacturing, tech pubs, procurement, and service — visit:

www.Lattice3D.com

3D Manufacturing Evolution

The global manufacturing sector is evolving rapidly. Recently the U.S. government has made efforts to strengthen the manufacturing industry and promote "reshoring" of domestic manufacturing operations that had moved overseas.

Germany launched a government-led high-tech Industrie 4.0 strategy, the "fourth industrial revolution."

China has its "Made in China 2025" initiative, a 10-year plan aiming to become a "manufacturing and production world power."

Japan has followed suit with its "Industrial Value Chain Initiative" in 2015.

At the same time, US companies are striving to increase productivity by making manufacturing smarter.

The globalization of manufacturing has accelerated the collaboration between countries and regions with different languages and cultures. This often results in language or cultural barriers. 3D models can help overcome these barriers. Using 3D models to communicate ideas reduces the need for text translations and fosters understanding across languages and cultures.

So, amidst the current manufacturing revolution, what must a global manufacturer do to win in the competition with its rivals around the world? One answer is to leverage 3D design data to optimize the global production process, from design and development to production, sales, and service.

Hiroshi Toriya is founder and CEO of Lattice Technology, Inc. (www.Lattice3D.com) and creator of XVL — an ultra-lightweight data format for 3D geometry and a container for authored information such as work instructions and PMI.