Operating space stations demands massive and complex information systems which in turn create challenges for the many participants to obtain the information they want. XVL technology, which enables easy and fast access of design information, is proving key to releasing that data for all stakeholders.

JAXA.

3D Data Usage Spreads to Outer Space
- Improving Lean Manufacturing Through 3D Data

by Dr Hiroshi Toriya
The ‘3D Model Search’ Interface Developed to Support Kibo, the Japanese Experiment Module (JEM), on the International Space Station (ISS) Program

In March 2008, JAXA’s pressurized experiment logistics module for Japan’s first manned space experiment module, codenamed “Kibo”, was launched to the International Space Station (ISS) on the Space Shuttle Endeavor, and installed by Japanese astronauts. On March 15, 2008 Astronaut Takei Doi became the first Japanese to enter the logistics module in space. In June that same year, Kibo’s onboard laboratory module was launched by the Space Shuttle Discovery, and installed in the International Space Station in a mission led by Akihiko Hoshide. In 2009, the external experiment platform and pallet will be launched so that various experiments, which can only be conducted in microgravity space, can be carried out for a span of more than 10 years. 3D CAD was used for the development of this state-of-the-art high-tech equipment, and the 3D models are expected to play increasingly important roles in the review of designs and operations. This chapter discusses an interview with Yoshiki Hashiguchi of the Human Space Systems and Utilization Mission Directorate at JAXA on the IT technologies supporting JAXA’s Kibo platform, as an example of how 3D data is rapidly expanding to the area of orbital space.

Kibo, the Japanese Experiment Module

JAXA was established in October 2003 as Japan’s head space agency. With more than 1800 employees, JAXA is involved in the R&D of space science, development of satellites and the rockets to launch them. Based on the long-term vision of “establishing free space activities using the best technologies available in the world”, JAXA is currently carrying out R&D projects jointly with several technical support companies and organizations. Of these, the Human Space Systems and Utilization Mission Directorate is pursuing the potential of space use by promoting manned space activities. The Directorate participates in joint international projects such as Kibo to promote technological innovation at home in Japan and inspire future generations to acquire scientific knowledge through experiments using the environment of space. The International Space Station is a space laboratory designed to carry out research activities that are possible only in space. It is the first international space project participated in by 15 countries including Japan, U.S.A., Russia, Canada, and Europe. Construction of the space station is steadily progressing, aiming at completion in 2010. As shown in Figure 12.1, the space station is massive, measuring 72.8 m in length by 108.5 m in width. The Kibo experiment module is located at its center. The space station is able to dock a space shuttle to replenish experiment equipment and supplies, and also has a habitation module.
Why XVL is Used for Space Development

According to Hashiguchi; manned space developments are the culmination of all scientific and technological achievements of humankind. They serve as venues for all human activities, and are linked to the future of all technologies. Manned space facilities are required to be completely airtight, as well as robust enough to prevent internal...
damage – a tall order when debris of even 1 cm (artificial suspended solids inside space) can cause damage when it collides with the equipment at speeds of several kilometers a second. They also need to have a contingency plan in the design to allow the crew to escape in the event of catastrophic failure. Kibo, which is about as big as a large bus, is composed of about two million parts, and represents a culmination of the achievements made so far.

Figure 12.2 shows the experiment module developed by Japan, under a 10-year research initiative making use of space environments. For example, the onboard laboratory is used for carrying out materials experiments and research for clarifying physical phenomena in the microgravity environment that is unique to space, as well as for conducting bio and medical experiments. The external experiment platform is, on the other hand, used for conducting experiments in environments exposed to advanced vacuum state and cosmic radiation. As outer space, which is mostly obstacle-free, has an extensive field of vision, it is also useful for observing astronomical bodies and the Earth. By June 2008, the onboard laboratory, which is the main module of Kibo, was installed, establishing a research system in space and opening the path for Japan to use space on a full-fledged scale. According to future plans, Japan will install and complete the external experiment platform as its final construction phase during 2009.

Space is both a vacuum and highly extreme environment, exposed to strong cosmic radiation. The labs, devices, transportation equipment and systems required for living and researching in space are therefore very complex. For these systems to operate normally, the management and use of technical information related to the space station is crucial. Since the start of development of the International Space Station, 3D CAD models have been used to manage design, assembly methods of configurations in orbit and to review assembly processes. As a part of this, JAXA has been integrating the 3D CAD models of Kibo and providing data to its partners. The data size of the full 3D model of Kibo is said to be between several Gigabytes to several tens of Gigabytes. While designers have no problems accessing and using such huge volume of data during the design process, people in later processes experience problems because they are not trained to handle such data nor do they have the systems to do so. If 3D design models, which are the fundamentals of manufacturing, could be used directly for the management of diverse information, the convenience attained would be immeasurable. JAXA thus was faced with the need for a means by which anybody to easily display and use 3D models of the installations.

Today JAXA uses virtual reality for some of its training programs, such as assembly simulations of Kibo, but currently displays just the specific module parts virtually on the computer. This doesn't help the astronauts understand the extent and the complexity of the equipment around them, especially if a lot of it is hidden by panels. If all the parts are displayed in 3D it is easier to virtually take off various panels that hide complex equipment so that the astronauts are better prepared to deal with the extent of the machinery around them. Since this is a project on such a massive scale, it is becoming more important to be able to display, and simulate, not just the equipment but all of the data being used and developed, on the space station and for the environment around the space station. As a result, JAXA is already planning to use its 3D models to more realistically simulate the platform plus all the numerical information gathered from the space station and from the environment around it to its full extent.
12. 3D Data Usage Spreads to Outer Space

As shown in Figure 12.3, the sheer volume of information for Kibo has dramatically increased from its development stage until it started operating, and will grow yet more when future projects are included. With this in mind, JAXA has been reviewing technologies which allow simultaneous use of lightweight 3D models and database information on the web. XVL, which delivers both lightweight data and use of 3D on the web, quickly became a focus of attention and was also tested for creation of 3D operations manuals and thermal analysis. Satisfied with the results, JAXA decided to adopt XVL as a lightweight 3D representation format. Furthermore, to build reliability and efficiency in the maintenance and operation of Kibo, JAXA built a database which allows easy access to all information on Kibo including 3D models. In doing so, the organization delivered a technology to easily retrieve massive product and part information through XVL.

Construction of the Development Information Integrated Database

JAXA does not actually carry out any type of manufacturing; its role is to coordinate and integrate aerospace activities. As shown in Figure 12.4, JAXA receives massive volumes of specifications, approval drawings, testing and analysis reports as results of the design work being undertaken on a daily basis. During design and development, the first and foremost challenge was to obtain the required design information as quickly as possible. To support these development activities, JAXA constructed an integrated database which allows fast information retrieval for management functions for each project,
and for dealing with discovered faults and failures. In this system, information is retrieved using a configuration tree of all the parts used in Kibo, as well as keywords, delivering an efficient information infrastructure to engineers, designers and operators, who are able to use the very wide variety of information and data for each part of Kibo.

Simultaneously, since the start of the development of the International Space Station, JAXA has been centrally managing design information using 3D CAD models, and all participating countries are designing 3D parts and modules, while NASA is constructing full 3D assembly models. Likewise, JAXA is also building 3D CAD models for the design of Kibo (Figure 12.5). Before Kibo’s production commenced, each assigned manufacturer carried out 3D design using their own CAD systems, with JAXA centrally integrating the 3D data. When the 3D CAD model of Kibo was ready, it was shared across the international teams and used to review various operations including construction simulation, onboard activities, and so on. From the start, 3D models have been used for the design and assembly of Kibo, providing the foundations for its use.

Why A 3D Search Interface is Required

Because JAXA’s database was so convenient, more and more operational information on Kibo was being uploaded onto the system. But at the same time, the growing usage also revealed the limitations of the system. Furthermore, in the operations phase of Kibo, users of the system started to include not just the module designers but now also operations management staff who are not at all familiar with design and development work. The design teams were highly familiar with parts names and were easily able to find required parts information from the two million parts in the database. However,
this proved extremely difficult for the operations management staff to duplicate. In addition, the operations staff had to access the system from more widespread locations, and this led to the need for an easier, more straightforward method to access the information. Operational information on Kibo, which will eventually span across ten years, will far exceed the volume of development information already available. There was now a critical need for a system which would allow users to visually as well as intuitively extract the data needed and this system would have to address and resolve all of these needs at once. JAXA thus proposed a 3D search interface applying Lattice Technology’s XVL format into the configuration parts tree and text search database that they were already using. (Shown in Figure 12.6.) As a result, their database system for developed evolved into the “Development and Operations Information Integration Database” system.

**Needs**

1. Use by operations control staff not familiar with development
2. Uses from various places
3. Massive volume of information

→ Requires **visual and intuitive access**

**Development and operations information** integration database system =

- **Configuration tree + Text search** + **3D model search**

Figure 12.5 3D Model Used for ISS Construction

Figure 12.6 3D Search Interface Needs
What is the 3D Search Interface?

The most significant feature of the 3D search interface is its ability to display a selected part in its full form using a 3D model, and systematically obtain all related information on detailed parts. Information on Kibo’s parts is stored in the database, comprising attribute information on each part and 3D models in XVL. This information is also linked. In order to extract specific information needed from the enormous pool of information available, it is far more efficient to use visual 3D data to first narrow down the search, to identify a part, and to deliver related data on that part.

Figure 12.7 shows how the entire 3D Model of Kibo is displayed at the beginning of the search process. The user is able to visually identify the part or sub-assembly desired, and click this to display information on the part. In this way, the configuration parts tree of Kibo is linked to the 3D model. In other words, when one part of the configuration parts tree is clicked, the 3D model of the selected assembly or sub-assembly is displayed. By selecting an individual part from the displayed assembly, the system displays the corresponding 3D data and related attribute information in ever increasing detail. Further details can also be searched as attribute information for each part.
Examples of the 3D Model Search

There are high expectations being placed on the 3D Model Search system for Kibo’s operations across the next ten years. One application of the 3D Model Search, for instance, will be in detecting any system or equipment malfunctions, which are inevitable in the harsh environment experienced by the International Space Station. Any such problems need to be dealt with swiftly, and for this, ground operation staff need to be familiar with all the mechanisms of the space station - which itself is composed of an enormous number of parts. Once any problems are identified, the ground team has to be able to rapidly work out how to repair them, and then send the appropriate instructions to the astronauts. Since it is impossible for the ground operations staff to go on site, they will be using virtual 3D models. (Figure 12.8 shows the specific example described below.)

There are four lighting devices in the experiment logistics module. If one of them should not light up, the ground staff would find the faulty location in the storage room in the 3D virtual model. As the model is exactly the same as the real room, they are able to quickly find the affected device visually. On clicking the specific device in 3D, the related information and 3D data can be rapidly reviewed, and will also include any prior defects as well as solutions. The ground staff can then swiftly transmit the repair instructions while referring to the data available. In this virtual XVL world, the information is as precise as if the ground staff were actually looking at the real thing.

The potential of this system is vast. For example, in space it is enormously complex and dangerous to inspect the exterior of the station. However, with 3D models, it is easy to see the exterior of the model and find the defects. To search for the location of an interior part is also easy in 3D: simply walk inside the virtual vessel! This feature is unique.
to 3D. For instance, in order to easily find components hidden by other parts, there is no need to remove the parts;—simply switch the display or make the 3D parts transparent. This support for ground staff will prove vital to the operations of Kibo in space over the next 10 years.

Future Prospects

Implementation of the 3D search system inside Kibo while in orbit is also being considered: If astronauts are able to work inside Kibo while looking at the same 3D models, they will be able to obtain highly critical information while collaborating with ground control staff. Currently, though, due to restricted communications within the space station, it is difficult to immediately access up-to-date data, which has led to the idea of having XVL models available inside Kibo but having to obtain all the other data and information from the ground.

The 3D Model Search interface, which is intuitive and easy to understand, is gradually proving to be useful not only for space station development but also for the operations of ISS. The fact that access to this data is not limited by geographical location is also proving a great benefit.

In 2009, JAXA plans to launch a manned mission - HTV (H-II Transfer Vehicle) - a space station fueling vehicle. And is planning to use the 3D Model Search interface for both its development and operation, as well as considering its use in the development and operations of unmanned artificial satellites. JAXA is already experimenting with the 3D Model Search in order to apply the system to other manufacturing activities.

In the case of JAXA, easy use of 3D information was being prevented by the enormous amount of information generated during the design, development and then operational phases. JAXA's top management also agreed that complex information had to be "visual" so it can be intuitively understood. Yet they also needed a mechanism to extract only the required information swiftly from more than 2 million available parts. Although the full benefit of 3D will only be truly seen in future operations, 3D data is already contributing heavily to JAXA's mission: "reaching for the skies, exploring space".

About 'Improving Lean Manufacturing Through 3D Data' by Dr Hiroshi Toriya.

This book, one of several published by author, Dr. Hiroshi Toriya, discusses how Japanese manufacturers are addressing the critical need to continually improve manufacturing processes across the entire enterprise. In the cases highlighted in this book, manufacturers are turning to 3D data practices and processes to enable greater leaness of manufacturing. This book discusses why this is a necessity in the current economic conditions and discusses real world examples through in-depth interviews with manufacturers of all kinds.

Originally published in Japan in 2008 by JIPM Solutions, this book is available in english via e-book from Lattice Technology, and is available at www.lattice3d.com