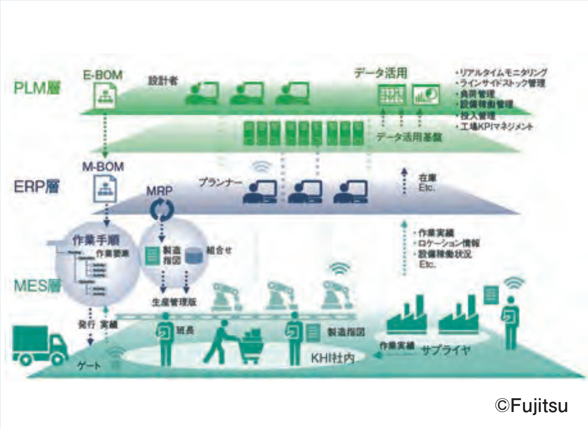
# Smart-K Enables Digital Integration of Information from Design to the Shop Floor




*In aircraft manufacturing, it is necessary to control an enormous number of parts based on strict quality standards. Until now, different pieces of information have been connected by paper and human labor to assure quality. Going forward, we are required to further enhance productivity while meeting strict quality requirements. Under such circumstances, we have successfully digitalized our work processes through digital transformation (DX), thereby achieving both quality assurance and productivity enhancement.*

## Introduction

Aircraft demand slowed temporarily due to the COVID-19 pandemic, but over the medium- and long-term, it is forecast to recover and surpass the pre-COVID-19 level [1].

## 1 Background

Aircraft require large-scale, complex manufacturing processes, but their operation long relies on human labor and paper. Digital transformation (DX) of factories is required to manufacture aircraft more efficiently with higher quality, as there are limits as to what can be done with conventional work processes that rely on human labor and paper.

## 2 Characteristics of aircraft manufacturing

The characteristics of aircraft manufacturing include a "characteristic body structure," "high-mix, low-volume production," and "strict quality requirements." Above all, an aircraft is a large structure that consists of over three million parts. To complete an aircraft, aluminum, titanium, carbon fiber reinforced plastic (CFRP), and various other materials are used in the appropriate locations after undergoing various processes, including machining, sheet-metal working, welding, chemical processing, and wiring. Meanwhile, aircraft need to minimize weight. As a result of pursuit of weight saving, many parts that appear the same at a glance have different specifications (custom-made parts), and these are generally manufactured in small lots. Since various products and processes exist, it is difficult to automate production lines and develop dedicated production lines; therefore, the job-shop production system has been adopted, whereby different products go through several hundreds of workplaces inside and outside a company in various routes. Unlike ground transportation vehicles, aircraft cannot stop operating in the air even if they experience trouble. To ensure safety, extremely strict quality requirements are imposed on their manufacturing processes, and certification systems and required specifications unique to aircraft exist, including JIS Q 9100 (Quality management systems–Requirements for aviation, space and defense organizations), which specifies requirements for ISO certification. Aircraft manufacturers must manufacture aircraft in accordance with these standards, ensure that records are kept properly, and promptly disclose such records as needed.

As described above, one difficulty unique to aircraft is that parts of various types that undergo complex processes must be controlled based on strict standards. On a shop floor for aircraft, a large amount of information, including drawings, work instructions, and records, have conventionally been controlled using paper to ensure quality, and it is even said that "Aircraft fly on paper." Millions of pieces of paper represent the accumulation of engineers' know-how and craftsmanship, and preparing various paper documents and connecting one piece of paper to another is an important duty in manufacturing processes. However, product structures are becoming more complex by the year, and an ever higher level of quality control is required. Conventional systems that rely on paper and human labor have nearly reached their limits.

## 3 Smart-K Project

To overcome this situation, we launched the Smart-K Project. The project's concept is to digitalize all information in the processes from drawing release, process design, production, and results collection, and to connect every work process digitally as shown in **Fig. 1** The project primarily consists of three activities: prompt, proper communication of design requirements; digitalization of work instructions; and aggregation and visualization of all data. The aim is not only to increase the speed and reliability of work through digitalization but also to enhance productivity through effective use of accumulated data.

This project covers operations and workplaces throughout the entire factory and necessitates the establishment of an extremely large system. Therefore, team members were assembled from the design, production engineering, production control, manufacturing, quality assurance, and information system departments in order to organize a new section, and the project was carried out in close collaboration with external partner companies, including Fujitsu Limited and SAP Japan Co., Ltd.

### (1) Prompt, proper communication of design requirements

(i) Background

In aircraft manufacturing, tests and auxiliary analyses should be conducted for the individual products to be manufactured in principle, but tests may be simplified or omitted by applying type certification to drawings. It is unrealistic to conduct many tests and analyses for each individual aircraft to be manufactured, so the type certification system can be said to be essential for business continuity. For the type certification system to function, repeatability must be ensured—in other words, one must have the capability to manufacture aircraft as per drawings and standards that have been proven by preliminary tests—and records from manufacturing processes must be controlled appropriately.

Ensuring repeatability requires ensuring that technical information is properly communicated to the shop floor (referred to as the "flow-down of technical information"). In practical work, three processes are necessary. First, design personnel create an engineering bill of materials (E-BOM) and drawings based on the customer's requirements and technical specifications. Next, production engineering personnel incorporate manufacturing specifications into the E-BOM and drawings, and then create a manufacturing bill of materials (M-BOM) and work procedures based on them. Finally, field workers carry out the work according to the work procedures developed by the production engineering personnel. The field workers are also required to properly record all necessary information, such as work results and

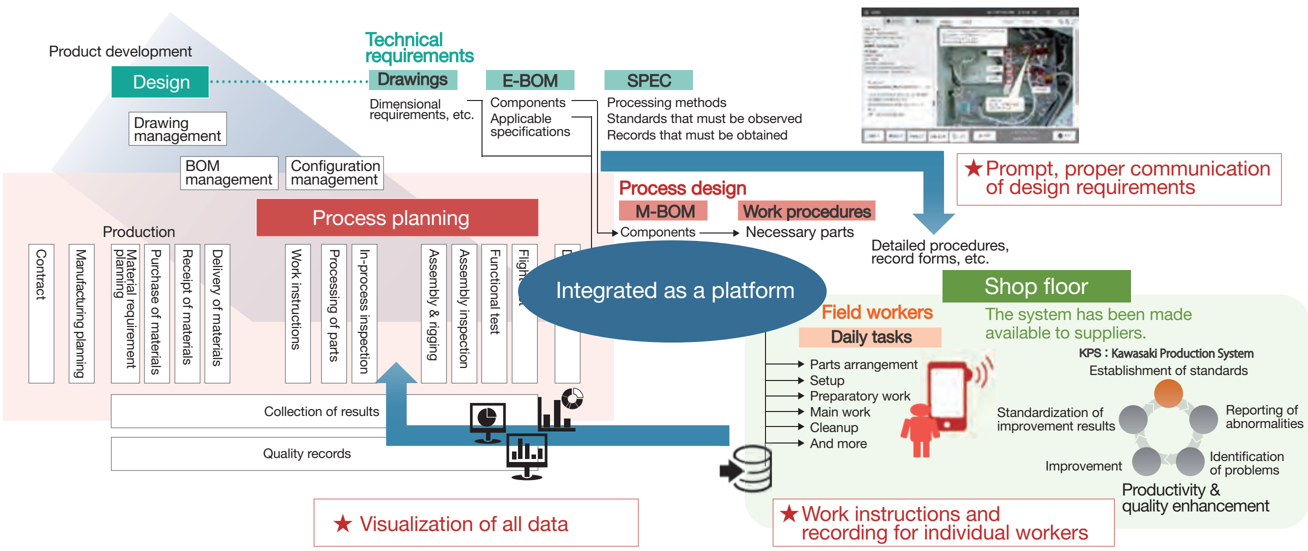



**Fig. 1** Concept of Smart-K

the names of the workers in each process. It is essential to store such records as quality records and make them available as needed, or ensure traceability in manufacturing.

(ii) Challenges

As already discussed, aircraft manufacturing involves a large-scale, complex shop floor, and in a factory, several hundreds of thousands of parts are flowing continuously via tens of thousands of routes. Given the enormous number of parts, technical information has flowed down by manually connecting a huge number of pieces of paper, but this incurs a huge amount of labor to reflect changes, such as design changes and process changes, and control information. In addition, though paper ensures traceability, if specific information is required, the desired information must be searched for among a nearly infinite number of pieces of paper, making it difficult to disclosure information speedily.

(iii) Solution policy

To address the above-described situation, in the Smart-K Project, we had the idea of converting paper-based information to digital data in order to handle the enormous amount of information more quickly and reliably. Through this project, we expect to create hundreds of millions of records across a wide range of operations, from drawing release to production. For appropriate data control, we first identified the challenges in our existing work processes and formulated ideal work processes to summarize our requirements. We examined well over 100 work processes. We consulted with the relevant departments, identified the necessary data and operational functions, and developed an integrated platform that can collect every piece of data necessary for operations as shown in **Fig. 2**.

This integrated platform covers many operations and is used by thousands of employees; therefore, it could not be implemented as a single system. Consequently, with the commercially available package SAP S/4HANA Manufacturing for Production Engineering and Operations (PEO) as the core, we organically linked multiple existing systems, including the integrated core business system ERP [2). Though PEO has a function for maintaining the consistency of manufacturing data, which matches with our goal, when we considered adopting PEO in 2017, it was quite a new solution and had not yet been adopted anywhere in the world. Thus, adopting such a system was a risky and bold move, but we made maximum use of PEO's standard functions to avoid additional development, and we successfully developed a large-scale system in a short time.

In the integrated platform, all data, from drawing release to production, is aggregated and stored, and each piece of data is linked with the others. This enables all technical requirements and change information for several hundreds of thousands of parts to be promptly communicated to the shop floor without omission. In addition, the integrated platform incorporates a unique mechanism for issuing work instructions to the shop floor and collecting results, which is described later. This ensures correspondence between instructions and results and makes it possible to know at a glance when, how, and by whom a product was manufactured. Thus, we

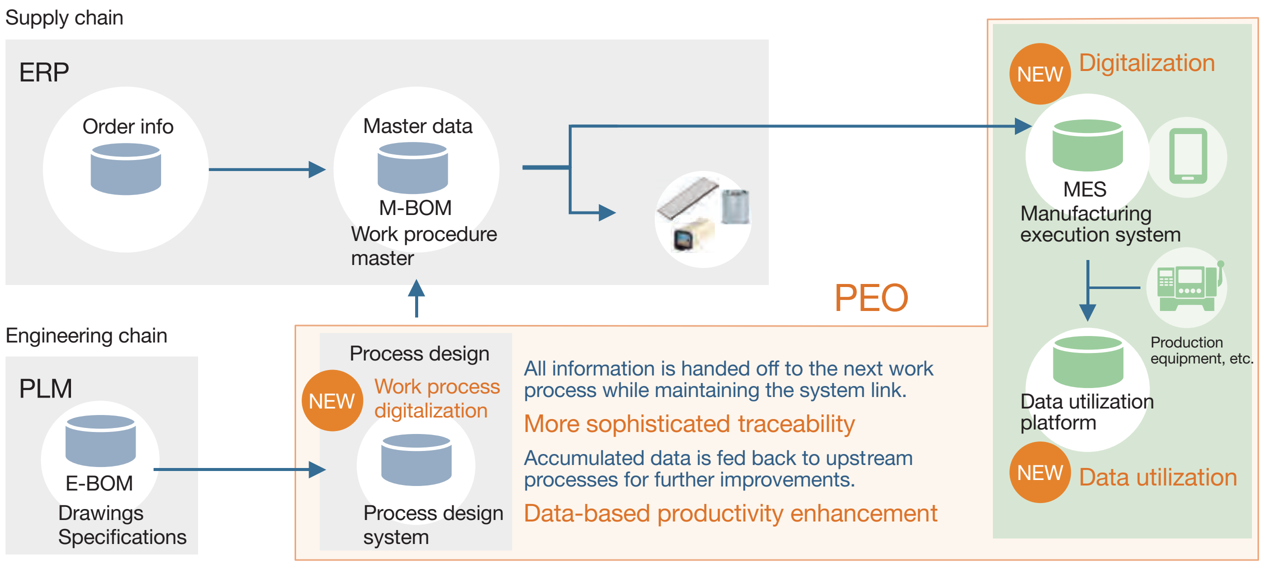



**Fig. 2 Integrated platform**

strengthened flow-down and traceability of technical information and prepared for future production increases.

**(2) Digitalization of work instructions**

(i) Background

With our unique production system KPS (Kawasaki Production System), we are improving our shop floor day by day to enhance productivity. Detailed work instructions for individual workers are a representative tool for iterating such an improvement cycle. Such instructions describe every action that workers need to perform in their field work on an element-by-element basis. Work is divided into smaller tasks so that even inexperienced workers can maintain high levels of work efficiency and quality. In addition, using these instructions, information on actual work times is collected, and differences between actual and target work times are analyzed to discover better work methods. The detailed work instructions for individual workers enable us to iterate an improvement cycle such that none of our workplaces are stagnant for even a single day.

(ii) Challenges

The detailed work instructions for individual workers can be said to be an accumulation of the shop floor's manufacturing know-how and our unique competitive strength. However, many of them are used in print form, and it takes a long time to create instructions and collect the results. Therefore, there is a limit to the number of times that the improvement cycle can be iterated. In addition, as previously mentioned, flow-down of technical information is required, but much labor is involved in frequently updating work instructions while maintaining consistency between the work procedures prepared by the production engineering department, which are higher-level instructions, and the detailed work instructions for individual workers. Thus, iterating the improvement cycle while maintaining strict consistency is difficult, so this is a challenge in using the detailed work instructions for individual workers.

(iii) Solution policy

In the Smart-K Project, we digitalized the detailed work instructions for individual workers used at each workplace, thereby reducing the amount of labor necessary to create instructions and collect results.The aforementioned integrated platform includes the function that the detailed work instructions for individual workers have as a manufacturing execution system (MES) in the ERP downstream. This enables people on the shop floor to easily create detailed work instructions for individual workers while maintaining consistency with the work procedures developed in the MES by production engineering personnel. In addition, the detailed work instructions for individual workers are stored in the MES as master data, where they are accumulated and refined as a source of competitive advantage.

The created detailed work instructions for individual workers can be displayed on workers' tablets as shown in **Fig. 3**. Workers can understand their tasks at a glance with

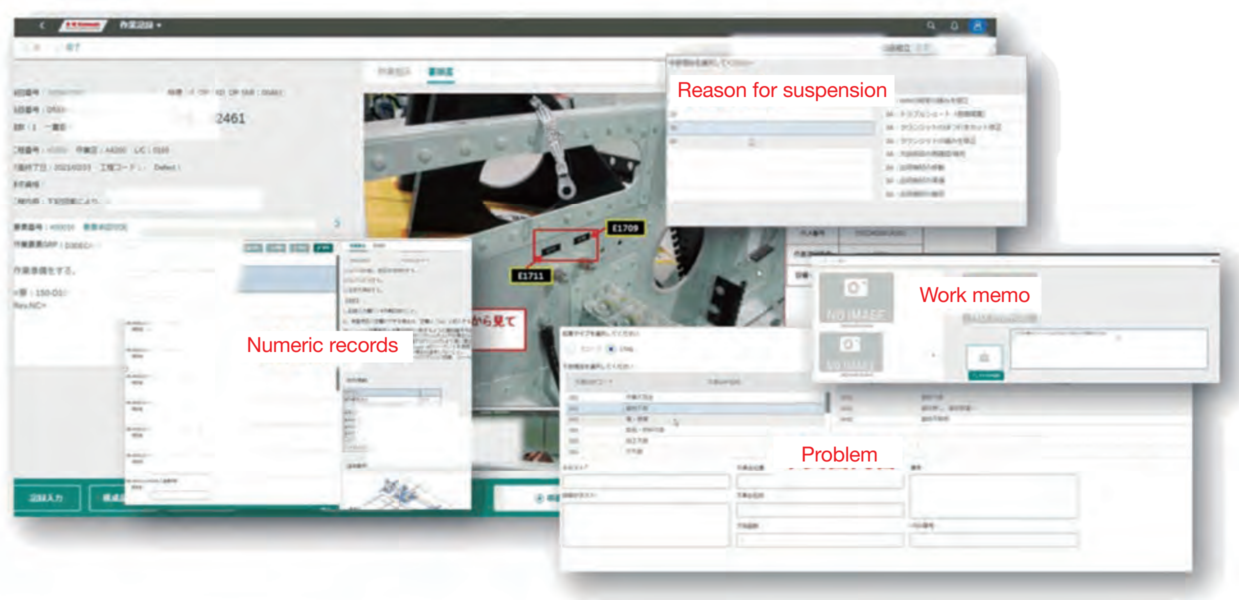



**Fig. 3 Detailed work instructions for individual workers**

graphics, including photos and drawings, and can browse relevant documents as necessary, enabling them to work without making mistakes. At the same time, results information can easily be collected from the tablets and accumulated on the integrated platform, enabling on-the-spot assessment of work efficiency. In addition, things workers notice and workers' know-how can be recorded with photos and text, which makes it possible to analyze actual work times and things workers notice in an integrated manner, thereby facilitating quicker, deeper improvements.

In this way, we have successfully established conditions under which we can speedily iterate the improvement cycle while maintaining the strict consistency required for aircraft manufacturing.

**(3) Aggregation and visualization of all data**

(i) Background

Thus far, we have discussed the collection and accumulation of data in factories. To improve quality and productivity, utilization of such accumulated data is important. On the shop floor, a shift is required from subjective decisions that rely on seasoned workers' experience and intuition to objective decisions based on data.

(ii) Challenges

On the aircraft shop floor, there are nearly infinite numbers of people, materials, and equipment, which makes it extremely difficult to accurately understand what is going on in the factory. In addition, generally speaking, data has been collected and analyzed by individual departments, so there are concerns that decisions may be only locally optimal.

(iii) Solution policy

As we have mentioned repeatedly, every piece of data in the factory has been aggregated on the integrated platform and can be accessed at any time. By using such data, we will conduct analyses across different products and departments to make decisions that are optimal overall, which will enable us to obtain ideas for further enhancing the factory's capabilities and noticing new things.

To effectively utilize data, we first visualized the accumulated data. For example, we have already implemented a function for monitoring manufacturing progress in real time, which enables us to know what is happening on the shop floor without going there. We will next expand the scope of visualization, aiming to eventually visualize every production activity. In addition to visualization, we are analyzing data for management. We have established a system to assist management in making decisions by using information obtained from production activities as KPIs (Key Performance Indicators) for factory operation and management as shown in **Fig. 4**. Going forward, we will provide information that contributes to management with the aim of realizing data-driven management.

In addition to analyses and visualization, we plan to provide more active feedback with data—in other words, to control and optimize factories with AI—through which


Fig. 4  Dashboard for management

we aim to reduce lead times and costs as well as to develop factories that are more efficient than those of our competitors.

## Conclusion

The Smart-K Project is a digital transformation (DX) activity for large-scale, complex aircraft shop floors. In this project, we developed an integrated platform and solved various challenges, including those related to ensuring quality and enhancing productivity. The system is already in operation for some models, such as BK117 and B787, and we will expand application to other models. Also, we will apply the Smart-K Project's philosophy and best practices to factories for our other products, thereby making our company "smarter."

## References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