Kawasaki Takes Aerospace System Product and Technology to New Heights

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Introduction

Established in 1919, the aircraft division of Kawasaki has developed in both the military and civil fields in line with the progress of aircraft and it has expanded into the defense system and space fields.

As the Aerospace Systems Company has recently moved the defense aircraft section into mass production stage of developed models, business is expected to continue to be stable. In the commercial aircraft business, much growth is expected because of a medium- and long-term global increase in passengers and cargo volume as a result of economic growth in emerging countries. Under these circumstances, we are pursuing further development by venturing into new business fields in addition to those extended from existing businesses.

1 Features of the Aerospace Systems Company

The Aerospace Systems Company is involved in a wide range of aerospace-related businesses with the objective of being an internationally competitive aircraft manufacturer in terms of quality, cost, and lead time as a leading company in the aerospace industry in Japan. We also continuously strengthen our technological capabilities highly appreciated by customers and the market and further improve the quality, cost and speed of our services to succeed in the midst of great international competition.

We restructured the organization in April 2018 as an aerospace system manufacturer that deals in aero engines in addition to aircraft, defense systems, spacecraft and other products. We aim to be an aircraft manufacturer that has a greater ability to integrate systems by merging the technologies and know-how we have on airframes and engines, and provide new values to the industry.

2 Overview of major products in each business field

(1) Military airplanes

We have played a major role in developing and manufacturing a variety of models including the T-4 intermediate trainer and the P-3C patrol aircraft. As the prime contractor of the development project of the first large aircraft made in Japan in 30 years, we completed development of the P-1 maritime patrol aircraft and the C-2 transport aircraft and are now engaged in manufacturing their production aircraft.

The P-1 is a rare aircraft that has an all new airframe, engine and avionics equipment specifically designed for maritime patrol missions. The P-1 can be used at low and high altitudes and speeds through the application of new technologies including the world's first operational fly-by-light control. After completing its development in FY2012, we have been delivering production aircraft to the Japan Maritime Self-Defense Force, where they will be used to ensure maritime security around Japan in place of the P-3C airplane.

The C-2 is the largest aircraft ever developed in Japan. The C-2's maximum take-off weight is about three times heavier than that of the C-1 and the C-2 can transport people, vehicles, pallet cargo and many other different forms of cargo with the latest load management system. After completing its development in FY2016, we have been delivering production aircraft to the Japan Air Self-Defense Force, where they will be used in air transit missions in international peace cooperation and other activities in place of the C-1 airplane.

We will continue to stably mass produce these two large aircraft as our leading products, while aiming to improve their capabilities and apply them to the derivative airplane business. Both of these models have drawn international attention through activities such as a ground exhibition of the P-1 (**Fig. 1**) at the Paris Air Show in June 2017 and that of the C-2 (**Fig. 2**) at the Dubai Airshow in November 2017.

Fig. 1 Overseas ground exhibition of the P-1 patrol aircraft

Fig. 2 Overseas ground exhibition of the C-2 transport aircraft

The T-4 intermediate trainer (**Fig. 3**), which Kawasaki developed as the prime contractor, has been actively used by the Blue Impulse team. However, it has already been more than 30 years since it was developed. We will promote project proposal activities to modernize the mounted systems and develop its successor.

Fig. 3 T-4 intermediate trainer

(2) Commercial airplanes

In the commercial airplane field, we have contributed to the international joint development programs for Boeing's wide-body aircraft, the Boeing 767, Boeing 777, and Boeing 787, in the U.S. and Embraer's regional aircraft, the E170 and E190, in Brazil by leveraging all of our engineering capabilities as an aircraft integrator, all the while accumulating technologies as we participated in these programs. In particular, the 787 (**Fig. 4**) is an innovative passenger aircraft that has used carbon fiber composite materials in place of conventional metals wherever possible. We have sophisticated technologies to design and manufacture the sections we are responsible for through joint development and have established our position as one of the foremost composite body

Fig. 4 Boeing 787 series

manufacturers in the world. The Boeing 787 family includes the Boeing 787-9 and Boeing 787-10 as derivative airplanes with extended bodies in addition to the basic Boeing 787-8 model.

We are now participating in the development of the successor of the 777, the Boeing 777X. The 777X (**Fig. 5**) is a next-generation aircraft wholly renovated to realize passenger comfort similar to the 787 by introducing new technologies applied to the 787 though it is a derivative airplane of the 777, whose body is made of metal. While the basic Boeing 777-9 production has been started toward delivery in 2020, the development of a short-body derivative airplane for ultra-long range flight, the Boeing 777-8, is also underway.

When manufacturing the 787, we succeeded in producing innovative composite material structures for 14 aircraft a month, an unprecedentedly high rate of production, through advanced automation such as automated placement of composite materials. We also internally developed the latest robot system and constructed and started operating a new factory to further promote automation in the manufacture of the 777X. In addition to high quality and efficient production through integration with a production method that we created during the production of conventional models to improve efficiency known as the Kawasaki Production System (KPS), we are preparing the infrastructure to shift to smart factories that include ICT and IoT in the future.

Through these efforts, we will further enhance international competitiveness in terms of quality, cost and lead time and attempt to participate in new projects such as international joint development of future commercial aircraft.

Fig. 5 Boeing 777X

(3) Helicopters

We have built up a solid technological foundation and internally made advancements in our research to develop our own helicopters since we first began producing and repairing helicopters under a license agreement that began shortly after the end of World War II. So far, we have developed the BK117 with Airbus Helicopters in Germany in an international joint project in the civil sector and the OH-1 observation helicopter for the Japan Ground Self-Defense Force in the defense sector.

The main feature of the OH-1 is its high maneuverability enabled by components such as a composite rotor hub. As it has been more than 20 years since its maiden flight, we are moving forward with research and proposal activities that include modernization of its electronic devices to enhance mission capabilities.

The CH-47 large transport helicopter (**Fig. 6**) operated by the Japan Ground Self-Defense Force and the Japan Air Self-Defense Force is actively used for purposes including disaster relief and international emergency assistance activities such as transport of supplies/people and aerial firefighting. We have continued to manufacture the CH-47, enhancing capabilities according to the mission based on a license agreement with Boeing.

The MCH-101 minesweeping and transport helicopter used by the Japan Maritime Self-Defense Force was manufactured by equipping Leonardo Helicopters' AW101, jointly developed by Italy and the U.K. and manufactured under a license agreement, with our proprietary minesweeping system and other systems. A CH-101 multi-purpose helicopter, which is akin to the MCH-101, is loaded onto the icebreaker Shirase that operates in the Antarctic waters, to transport supplies and support the research expedition team.

In the defense helicopter business, we are offering derivative models for new missions. We have also started entering into comprehensive logistics support agreements including inventory guarantee of supplies based on analyses and forecasts from past operation records and guarantee of the availability ratio to support efficient operation.

The BK117 commercial helicopter is the best-selling model with sales of more than 1,400 units around the world since the acquisition of a type certification in 1982. Operated by private companies, municipalities, or other organizations, the BK117 is actively used in a wide range of fields including people transport, firefighting, rescue, police, emergency medical service, and media and it has earned a great reputation. We have also continued to develop derivative models and launched the latest model, the H145//BK117 D-2 (**Fig. 7**) in 2016. We are developing new technologies including research on safety enhancement in rescue missions under severe conditions as Japan's only manufacturer and supplier of commercial helicopters.

(4) Defense systems

We have developed all the anti-tank and anti-landing craft missiles in Japan. The latest Medium range Multi-Purpose missile was developed as the successor of the Type 79 anti-craft and anti-tank missile and Type 87 anti-tank missile and is now mass-produced and delivered to the Japan Ground Self-Defense Force. We introduced the latest technologies including target detection using information from infrared images and millimeter radar in this missile. Furthermore, we fulfilled our contract with the MOD for a prototype of a future network-capable multi-purpose missile system in FY2012 and have accumulated expertise such as infrared target identification technology that uses artificial intelligence (AI) and the networking technology to realize the optimal system operation leveraging network information.

We have also developed the Small & Smart Target Drone System by applying the guidance and control

Source: Ministry of Defense (MOD)

Fig. 6 CH-47 large transport helicopter during firefighting

Fig. 7 H145//BK117 D-2

† Realized the world lowest level of noise in its class, better hovering performance and longer lifetime through adoption of a new tail rotor and other components.

technologies that we gained by developing missiles. This target drone is employed as the air-launched small aerial target for fighter jet training by the Japan Air Self-Defense Force and has contributed to an increase in training opportunities by reducing the cost to about one-fourth of the conventional one. In addition, we have altered this drone to support anti-aircraft firing training by the Japan Ground Self-Defense Force and plan to start delivery in FY2018. This target drone uses the KJ14, a highly versatile small turbo jet engine developed by Kawasaki. We are also actively making proposals for derivative models for further expansion of its applications.

In addition, we are developing high power laser systems, as we consider them to be an innovative technology that could be a game changer in future defense missions. We have researched and developed defense applications based on iodine laser technology which was developed for industrial purposes over a long period of time. Now, we are developing a fiber laser system (**Fig. 8**) that allows for size reduction, instantaneous response, and lower cost in preparation for equipping the air defense system with it in the future.

(5) Space

We have contributed to space development in Japan in many different fields including rockets and space stations. We are Japan's only developer and manufacturer of fairings, which store and protect satellites in the tips of rockets, and we are currently building the fairings for rockets including the H-IIA/H-IIB, Epsilon, and the H3, whose first model is scheduled to be launched in 2020. For Japanese Experiment Module, named “Kibo” on the International Space Station, we developed and manufactured key parts such as the airlock that divides the pressurized section where astronauts stay from the vacuum of space. Airlocks are frequently used for purposes such as receiving supplies, recovering specimens after experiments have been conducted outside the station and deploying small satellites. We are now focusing mainly on research and development toward realization of a satellite that removes space debris (**Fig. 9**) as there is a lot of it adrift in orbit and it could collide with satellites or space stations. We are also stepping up efforts in related businesses and in developing many different satellite subsystems.

(6) Aero engines

(i) Aircraft engines

The beginning of our aircraft engine business was the development of the “Ne” series engine during the war, and during Japan's postwar years, we started overhauling engines made by Western manufacturers in U.S. military aircraft. We now manufacture and overhaul many aircraft engines such as the T53 engine for the UH-1 and AH-1 helicopters, the T55 for the CH-47, and the RTM322 for the MCH-101 and CH-101, all of which are used by the Self-Defense Forces. We have also participated in the design and manufacture of parts in the five-country joint development project of the V2500 engine for the Airbus A320, which started in the 1980s.

We enjoy a close collaborative relationship with Rolls-Royce headquartered in the U.K., one of the world leading aircraft engine manufacturers for large commercial aircraft. The bond of our strong friendship has been nurtured since 2004, when we were given our first opportunity to manage all the processes from design to assembly of the Intermediate Pressure Compressor (IPC), one of the major modules used in the Trent 1000 engine for the Boeing 787. Since then, we have been in charge of the IPC module in the development of the Trent XWB engine for the Airbus A350 XWB and the Trent 7000 engine for the Airbus A330 neo and have shipped more than 1,000 modules so far.

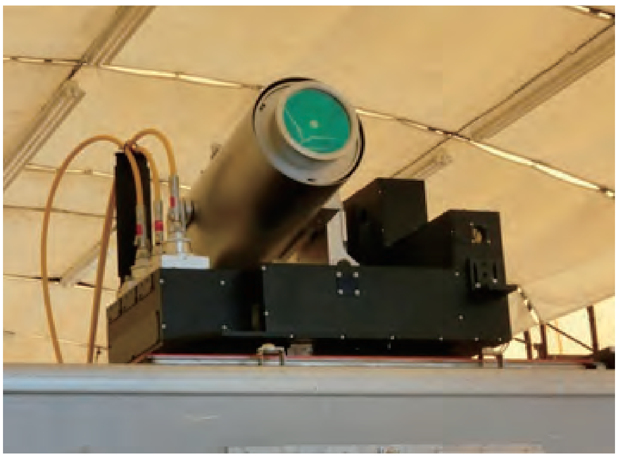

Fig. 8 High power laser system (fiber laser system)

Fig. 9 Debris removal satellite

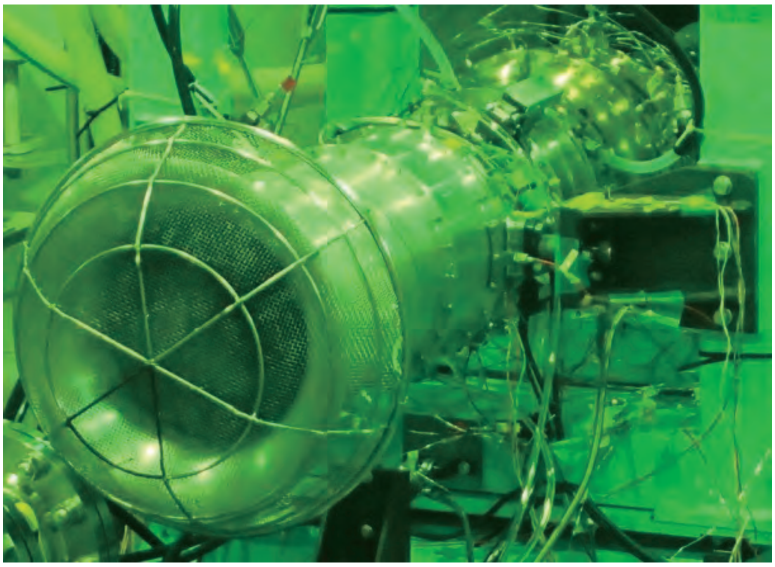

Fig. 10 KJ100 engine under test

We have been developing technologies for low NOx combustors for a long time as one of our proprietary technologies while addressing environmental regulations that get stricter year by year. Currently, we are developing technologies for the next-generation of engines for medium-size commercial aircraft.

In addition to the KJ14, which is mounted in the autonomous small target drone for the Japan Air Self Defense Force and the Japan Ground Self-Defense Force, we are also developing engines such as the KJ100 (**Fig. 10**) under the concept of small size and high power, aiming for their use in aircraft including future high-speed target drones.

(ii) Aircraft gearboxes

We develop, manufacture, repair and overhaul aircraft gearboxes including transmissions for helicopters, accessory gearboxes for aero engines, and the T-IDG (Traction Drive Integrated Drive Generator) for aircraft, which was developed by incorporating the Traction Drive CVT (Continuously Variable Transmission) into our product. We have also started developing technologies for gearboxes for next-generation aircraft and manufacturing fan drive gear systems for aircraft engines.

3 Technology development

(1) Artificial intelligence (AI) technology

Not only do we focus on airframe-related technologies but also on the mission avionics technology accumulated through the experience it gained in projects such as the development of the P-1. We have also fulfilled our contract with the MOD for a prototype tactical decision support system using AI technology (**Fig. 11**), which supports decision making of commanding officers in flight. This system is expected to prove very effective during operations. We regard this technology as the core technology of future modernization and derivative model businesses and are always looking for ways to use it in the many businesses of the future we are engaged in such as mission planning and operation control of autonomous unmanned aerial vehicles. In addition, we are conducting research on standardizing application software to make it operable in different computer environments with the aim of accelerating technology deployment.

AI is becoming increasingly practical and is being applied in a variety of industrial fields at an accelerating pace. We are also conducting research on decision making, action planning, and evaluation in addition to

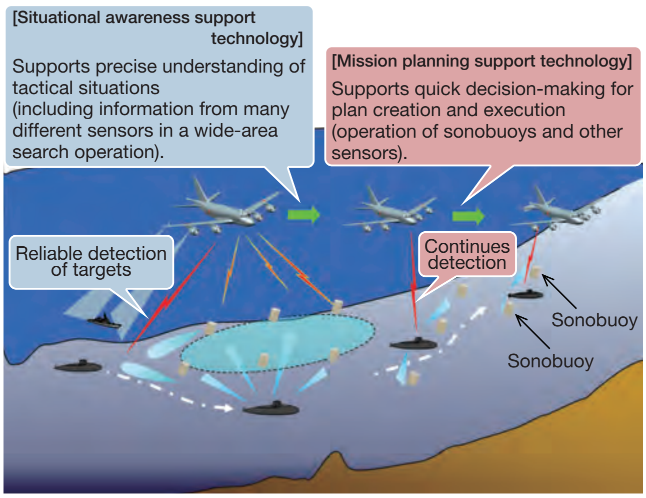

Fig. 11 Overview of tactical decision support technology

detection of signs of failure from information such as data accumulated during the development and operation of aircraft, and are considering application and development for future products such as crew support and expansion of the autonomous range of aircraft.

(2) Aircraft-related simulator technology

We can verify the system design before actual flight by having internal and external pilots evaluate the flight characteristics, visibility of instruments, operability of devices and other factors using our simulator for research and development during the development of new aircraft or internal research. The simulator exhaustively models the external environment including atmospheric conditions in addition to the movement of the aircraft and precisely simulates cockpit equipment including displays, control elements and instruments. This makes it possible to review designs through pilot evaluation and locate system defects at an early stage.

We have also developed pilot training simulators and maintenance training simulators for the aircraft such as the P-1, C-2, and MCH-101 based on the simulator technology we have accumulated so far by adding simulation elements in the real world such as the fuselage system, field of view, acoustics and vibration and delivered them as products, contributing to improvement in the efficiency and effectiveness of customers' training.

In addition, we are researching advanced simulator technology in which actual aircraft and multiple simulators are linked to realize training for complex missions where aircraft, ships and other vehicles interact with one another for product development in the future.

(3) Aircraft systems technology

Regarding aircraft systems technologies, we are conducting research and development on sophistication of system development on a more advanced level including model-based development that improves development efficiency and design quality, and high efficiency systems such as power and thermal management to address energy saving and cost reduction that is under way on a global scale to acquire foundational technologies for the realization of future aircraft. We are also conducting many different research projects on mission-related systems that are able to support an increase in applications of transport or other aircraft and instrumentation-related systems and network-type telemetry communication that supports next-generation aircraft and space equipment in the light of domestic and overseas situations.

(4) Technologies related to compressors, combustors and gears in aero engines

We are responsible for the design of an increasingly large number of parts as a result of its long-time collaboration with Rolls-Royce and striving to enhance our technological capabilities in order to become a “module integrator” that designs and develops compressors by ourselves in the future.

We are researching the application of ceramic matrix composites (CMC) to combustors in a NEDO project. CMCs are expected to be used in aero engines as a light, heat-resistant composite material. We will attempt to participate in new engine projects based on these technologies.

We also made it a goal to start a maintenance, repair & overhaul (MRO) service for commercial engines as a business within the next few years and to be an original equipment manufacturer (OEM) of manned aircraft engines in the future. To achieve this goal, we are constructing a strong technological foundation and organizational structure.

In the future, the demand for aircraft gearboxes will increase in line with the growth of the aircraft market and the market for high-capacity generators will increase as a result of the electrification of aircraft. However, only a handful of suppliers have advanced design and manufacturing technologies or have experience developing and manufacturing aircraft gearboxes. Considering such circumstances, we will continue our research and development to further improve our products in terms of their functionality and performance, pursuing our goal to become one of the top aircraft gearbox manufacturers in the world.

(5) Composite material-related technology

With excellent characteristics, namely, lightness, high strength, high rigidity and high corrosion resistance, carbon fiber composite materials have been increasingly applied in the aerospace field at a fast pace. Typical examples include commercial passenger aircraft such as the 787. We started development of materials that can be applied to commercial aircraft from early on and developed a material known as KMS-6115, according to our own standards. KMS-6115 was approved by the aviation bureaus in Japan and overseas in 1999 and was used in the BK117 as well as the P-1 and the C-2.

We also developed KMS-6125 through joint research with a material manufacturer in 2017 to meet the recent demand for low-cost high-rate production. This material has two remarkable features. The first is low-pressure formability that realizes good characteristics only using an oven and vacuum pump without having to use the expensive pressurizing and heating facilities required for conventional composite materials. The second feature is an excellent laminating characteristic realized by the automated placer (**Fig. 12**). KMS-6125 is highly expected

Fig. 12 Automated placement of the carbon fiber composite material KMS-6125 prepreg

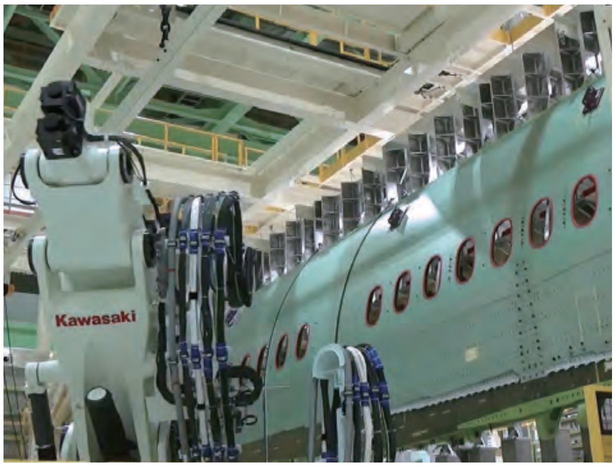

Fig. 13 Large-diameter boring robot system

to contribute to cost reduction in the future through applications in space equipment, airplanes and other products.

Regarding manufacturing technology, we are developing the automation and precision improvement technologies for parts with complex shapes assuming use in the fuselage structure of airplanes and rotorcraft and we are strengthening its overall competitiveness by focusing on low cost and stable quality.

On the other hand, composite materials tend to suffer more damage than metal in a lightning strike and therefore require critical lightning protection design. For this reason, we have been developing an analysis method to predict the damage that would occur in the event of a lightning strike with JAXA since 2012. We are also making lightning damage analysis more sophisticated. Measuring the temperature and distortion inside the composite materials using fiber optic sensors and taking photos with an ultrahigh-speed camera allows us to clarify how composite materials are damaged by a lightning strike.

(6) Manufacturing technology

To strengthen competitiveness to win new contracts and improve profits in each type of project, we are developing manufacturing technologies that lead to reduced costs and improved efficiency.

We are developing assembly technologies to reduce labor cost and lead time. We have completed development of the processing accuracy and large-diameter drilling technologies for drill robots and applied them to the manufacture of the 777X (**Fig. 13**). We are also developing automatic fasteners and sealers using robots.

We have continued to develop the technologies for sheet metal to reduce assembly costs and weight through structure integration with friction spot joining (FSJ) and friction stir welding (FSW). Although part accuracy has been a challenge for sheet metal forming, we are in the process of automating chip forming and roll forming, and improving the forming accuracy, aiming for accuracy equivalent to that of machine processing.

In the machine processing field, we are developing a cutting technology suited to the vibration characteristics of machine tools rather than only depending on the introduction of state-of-the-art machine tools and are thus improving the processes in an integrated way. For shorter lead times, we are also developing cutting tools for composite materials while developing low-cost setup robots.

Given the recent application of IoT to production, we are also innovating production using the IoT. For example, we are considering traceability automation by an identification system that uses RFID (Radio Frequency IDentification) tags. In order to achieve this objective, we are conducting field tests for individual identification.

Conclusion

To improve our international position as an aerospace-related company, Kawasaki encourages commitments such as further expansion of market share, promotion of international joint development and manufacture projects and strengthening of product proposals with new concepts all centered around our core businesses. We will also focus on advancing foundational technologies including materials, design, evaluation, production, and operation support as the source of the international competitiveness required for them. On top of that, we will step up to the challenge of conducting research and development of technologies for labor saving, energy efficiency improvement, system integration, safety guarantee, reduction in environment loads and other areas needing further development to provide new values through such development.