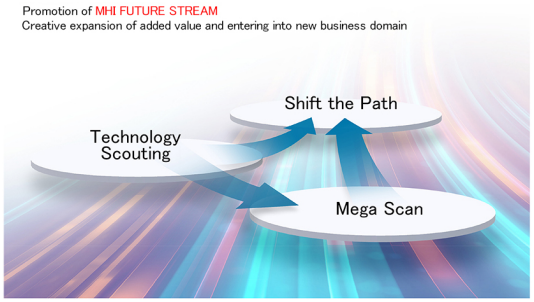
MHI FUTURE STREAM
"MHI FUTURE STREAM" – Creating Group's Future



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To continue to contribute to society and humanity through the provision of machine systems, it is necessary for Mitsubishi Heavy Industries (MHI) Group to be a company that can sustainably grow with the capability of responding to rapid changes in the social agenda, value, technological innovation, etc.

MHI FUTURE STREAM is an activity for setting our business direction according to the several possible scenarios that are formulated based on the big picture of changes in the political, economic, social and technological situations surrounding our business from a medium- to long-term perspective. This report introduces our MHI FUTURE STREAM activity and presents the future vision obtained through it.

1. Introduction

MHI Group has contributed to the progress of society through the provision of machine systems that make up social and industrial infrastructure. In recent years, we have been facing complicated social agenda (as represented by SDGs*), diversifying perception of value and accelerating innovation of technologies such as digital, biology and etc. To continuously contribute to society and humanity under such circumstances, we have to create a deep insight into what is happening in relation to these challenges, perceptions of value and technologies, and as a company, be responsive to these changes in a flexible manner. (*SDGs: Sustainable Development Goals)

MHI FUTURE STREAM (MFS) is a project that will enable MHI Group to continuously and diligently transform itself in such a way that it will stay in demand by society for many years to come.

2. MFS framework and management process

2.1 Exploration and exploitation management processes to create new value for uncertain future

When it comes to today's market and technological changes, as characterized by VUCA (i.e., volatility, uncertainty, complexity and ambiguity), looking through the future is difficult. It is therefore not always easy for the business divisions/departments of our company group (Business Function) to shift to a new business territory. This is because when performing agile reformation of the business foundation and organizational climate, which have been optimized through the ongoing businesses, while managing them effectively at the same time, we have to take a fair amount of risk and cope with considerable difficulty.

The "Exploitation Process" , which is a conventional process, denotes the optimization of business management efficiency. When shifting the business direction, in addition to this process, we need a new process called the "Exploration Process" to gain insight into the future from a broad, comprehensive perspective, generate hypotheses in relation to business and technological innovation and verify them on a trial-and-error basis(1).

The Shared Technology Function plays a leading role in the "Exploration Process". While

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collaboration with relevant divisions/departments of the Business Function is maintained, business and technological innovations are tested from a medium- to long-term perspective without any constraints by the ongoing businesses. The business ideas that have passed these trials advance to the next stage (i.e., "Exploitation Process") and are shared as growth strategies by all the group companies. During the transition between these two processes, some mismatches incompatible with the existing business foundation or organizational culture may be found. It is therefore important for the manager and the innovator to have a close dialogue and provide leadership that can make the transition work organically.

2.2 MFS's three approaches: Mega Scan, Shift the Path and Technology Scouting

To make both the "Exploration Process" and "Exploitation Process" work, three approaches are taken in MFS: "Mega Scan", "Shift the Path" and "Technology Scouting" as shown in **Figures 1 and 2**.

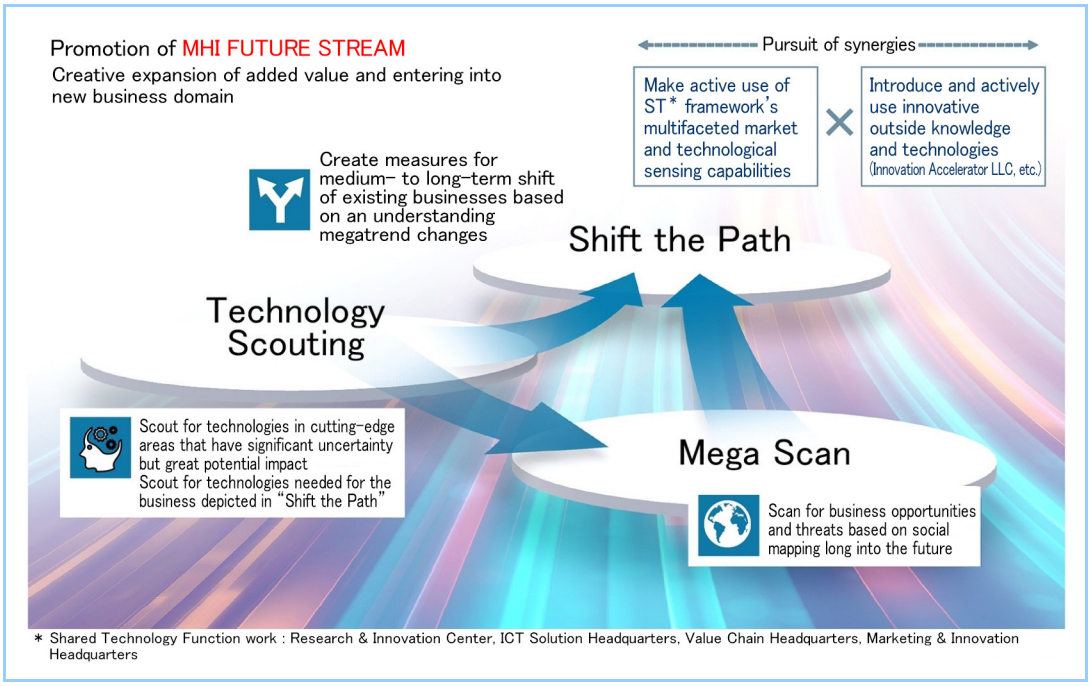

Figure 1 Three approaches of MHI FUTURE STREAM

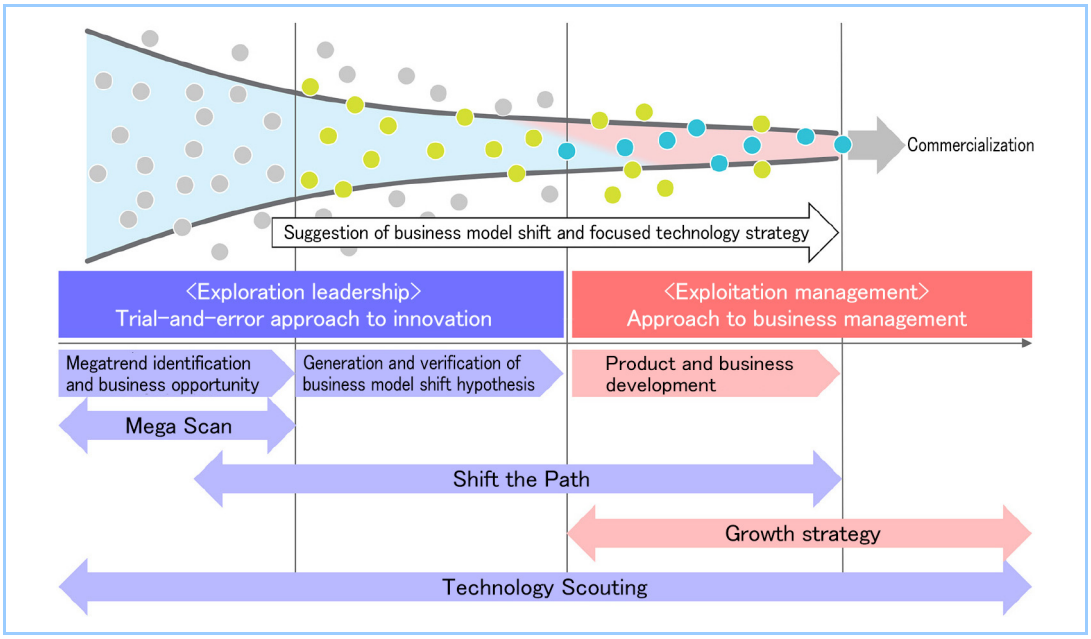

Figure 2 From MFS, business model shift/new business conception to development of growth strategy
(Blue: led by Shared Technology Function. Red: led by Business Function)

In "Mega Scan", society in 10-20 years in the future is predicted from a broad, comprehensive perspective, and based on the obtained image, possible change pattern scenarios are formulated considering wide-ranging possibilities in the market and technology to suggest possible business opportunities. Through this approach, many dialogues are held with experts and innovators both inside and outside our companies, and insight into the future and vision are created with multiple perspectives in terms of the market and technology.

In the approach of "Shift the Path", the insight and vision obtained by "Mega Scan" are used to construct possible scenarios for changes in each of the business areas. The market and technological innovation hypotheses are then generated (such hypotheses are difficult to conceive if the perspective available is only from a single division/department of the Business Function), followed by the stage to develop them into action. In MFS, this "Shift the Path" approach serves as a junction between the "Exploration Process" and "Exploitation Process". While cross-sectoral communication between the divisions/departments of management, technology and business is constantly carried out, the process of trial and error proceeds and action is taken accordingly.

"Technology Scouting" has two key concepts. One is a technology that has the potential to have a significant impact on the medium- to long-term insight and vision obtained in "Mega Scan". The other pertains to a technology needed to realize the innovation hypotheses generated through "Shift the Path". These two technologies will be invented together with external partners.

Although highly uncertain, the disruptive technology would have a significant impact if realized. Mainly through the newly-founded Innovation Accelerator LLC, the creation of new knowledge that had not been possible before proceeds at the discretion of the research development leader.

3. Medium- to long-term future vision

Described below are some examples of the market and technological insight and vision into the future obtained by "Mega Scan".

3.1 Environmental and energy perspective

(1) Electricity-based energy system and changes in market

Energy can be likened to the flow of blood in society, and safety is a prerequisite. In addition, it is also necessary to supply energy in a stable manner (Energy Security), improve the efficiency from an economic perspective (Economic Efficiency) and achieve environmental compatibility (Environment) all at once. To realize this 3E+S, it is necessary to implement multifaceted initiatives based on a comprehensive understanding of relevant issues ranging from energy supply to demand, including the national/regional energy situations, socio-economic structure, environmental regulations and policy discussions behind them.

When considering this from the perspective of the electric power system, we need to understand not only changes on the supply side such as power generation and transmission/distribution, but also those on the demand side of the industrial, civil and transportation sectors. In particular, rapid advances in technological innovation such as renewable energy, energy storage and digitalization may bring about dramatic changes in the market structure because of the gradual shift to a new electric power system through simultaneous development of the following: (a) realization of highly-efficient large-scale thermal power plants and low-carbon centralized power source systems through carbon capture, (b) changes in the function and usage of centralized power source systems mainly for the purpose of system stabilization, (c) extensive introduction of renewable energy to meet carbon-free demand and cost reduction, (d) new green-fuel such as hydrogen with the use of renewable energy, etc., (e) expansion of energy storage for system stabilization to shore up the extensive introduction of renewable energy, (f) structural changes in the power distribution industry owing to the introduction of renewable energy to the power distribution grid system and the use of distributed power source systems, (g) advanced energy management that transfers the energy value and network balancing systems to power demanders such as factories, buildings and households, and (h) sophistication of VPP* aggregation through digital technologies (**Figure 3**).

(*VPP: Virtual Power Plant)

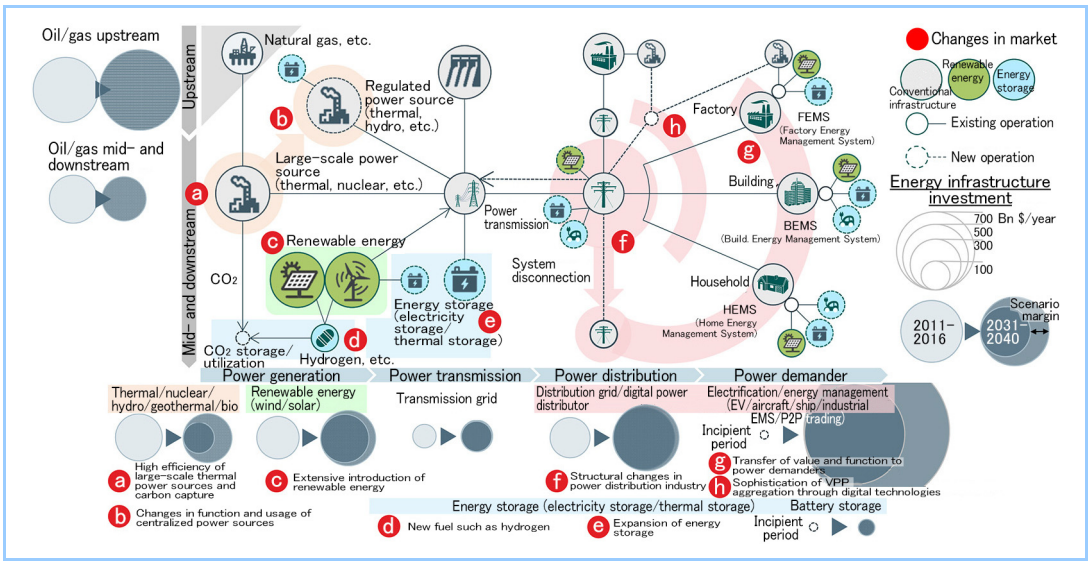

Figure 3 New electric power system and changes in market[(2),(3)]

(2) Carbon neutral society and market needs from perspective of carbon cycle

Since the Industrial Revolution, emissions of greenhouse gases such as CO_2 have rapidly increased because of fossil fuel consumption involved in the economic activities of human beings. It is understood worldwide that the risk of climate change is consequently increasing.

Further increased emissions of greenhouse gases as a result of population growth and economic expansion in the future are concerns. To realize the carbon-neutral society proposed by the Paris Agreement, innovation is required to make it feasible to reduce CO_2 emissions and elevate the amounts of CO_2 absorption and fixation with economic reasonableness. Specifically, for example, innovations in relation to expanded energy-saving features and renewable energy applications, electrification, the use of low- or zero-carbon fuels, recycling of resources, and carbon fixation and cycle through CCUS*, etc., are considered necessary. (*CCUS: Carbon Capture, Utilization and Storage)

People's perceptions of value change and diversify, new social systems and technological innovations may bring about changes in the market structure, which can deliver a new business based on a totally different value as shown in **Figure 4**.

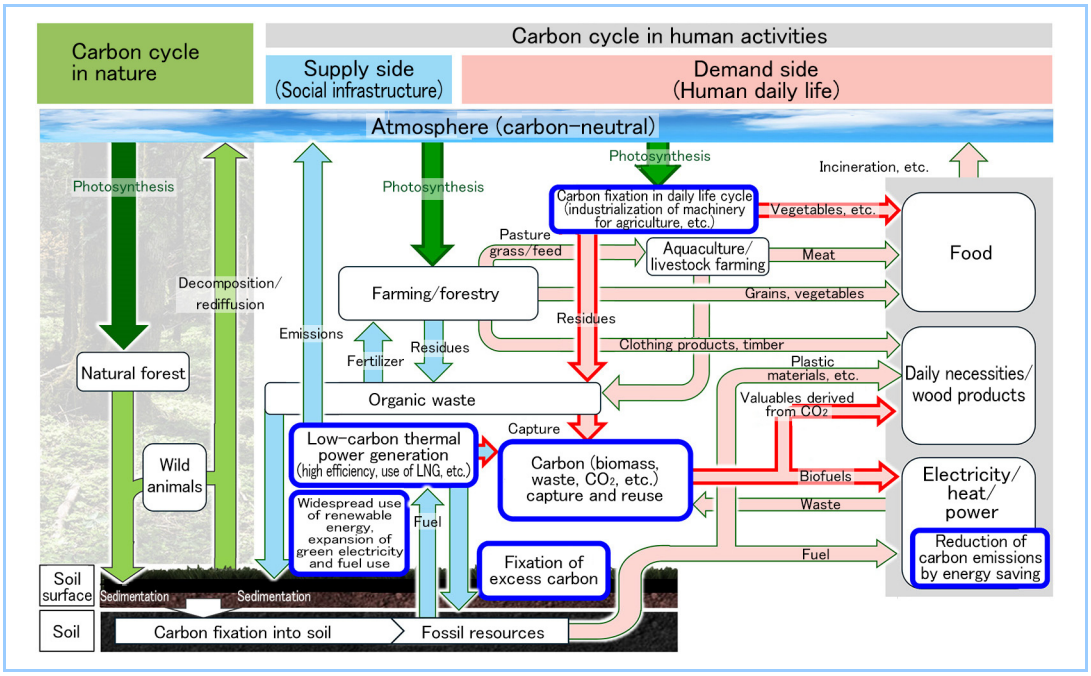

Figure 4 New market needs for carbon neutrality

3.2 Perspective of machine system advancement

(1) Changes in the value of machine system production

In "Mega Scan", we pay attention to changes in the value of machine systems in addition to changes in each of the markets such as the environment and energy.

Since its foundation, MHI Group has contributed to the progress of society through the provision of the machine systems that make up social and industrial infrastructure. However, the technological innovation taking place in recent years is gradually changing its value.

Conventionally in machine system production, the realization of the value of functionality through sophisticated adjustment of many parts had been highly valued. Recent advancements in materials and micro fabrication technology, however, favor a compact module that is equipped with many functions, thus reducing the value of sophisticated adjustment in machine system production while increasing the value of compact modules. Modern development in digital, communications and control technologies has enabled the autonomy and automation of machine systems, having machines interconnected with each other to work as a single unified system and fulfill the designed purpose. The intelligence of machine systems is of increasing value (**Figure 5**).

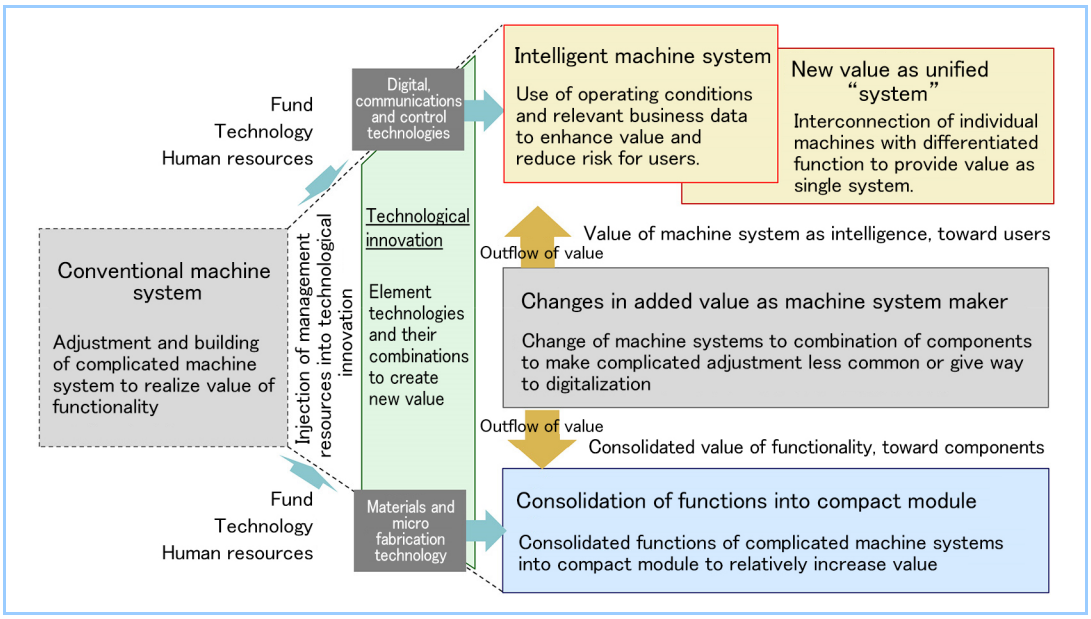

Figure 5 Changes in value of machine systems

(2) Intelligent machine system

The intelligence of machine systems does not simply mean the system's autonomy and automation, but denotes machine systems that can collaborate with people using added knowledge about business and operations, as well as related services. With this evolving intelligence of machine systems, the following things are expected to happen: (1) machine autonomy will transfer some functions from humans to machines and lead to collaboration between humans and machines, (2) as a change in e system operation, unattended operation will be made as a standard mode or segmented functions will be controlled as a group and (3) some of the human/organic functions will be integrated with those of machines and human capabilities will be enhanced. MHI Group is also considering the possibility of turning such changes into an opportunity to create a new business style (**Figure 6**).

Since the Industrial Revolution, labor has been divided between humans and machines by allowing machines to take on some of the tasks that humans conventionally conducted by themselves (e.g., carrying heavy objects and simple/routine work). Under such circumstances, the sophistication of machine intelligence through added knowledge about business/operations will enable machines to be partly in charge of the recognition, judgement and manipulation processes. The relationship between humans and machines will become collaborative. As an example in the industrial field, machine maintenance and operation (the execution of which has been dependent on the expertise and experience of skilled professionals) will be conducted

autonomously, improving business efficiency. Moreover, such autonomy and automation based on operation data will facilitate operational transparency. The clarified asset value of machines in the business will make flexible investment activities possible.

The further development of human-and-machine collaboration in accordance with the evolution of intelligent machine systems will make the relationship between humans and machines closer. In a society like this, people's capabilities can be improved by machines (human augmentation)[4] and people use autonomous machines to satisfy their wants such as physiological appetites and desires for safety and security. Moreover, other types of desires such as self-fulfillment are expected to be realized through collaboration with machines. When this altered relationship between humans and machines becomes more common, it will be necessary to design machine systems in consideration of people's experience and emotional value. MHI Group will contemplate what the machine system should look like and how people and machines can collaborate with each other to bring happiness to people. Forming an image of how things should be, we will provide these new systems to society.

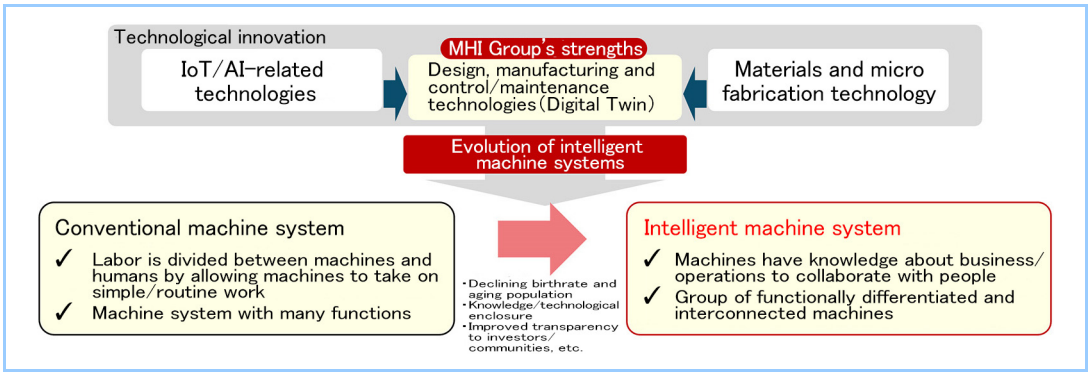

Figure 6 Evolution of intelligent machine systems

(3) Consolidation of functions into compact module and electrification of machine systems

When looking at power source technologies for machine systems, technological innovation has changed the machine system configuration as well as the industrial structure. Since the practical application of external- and internal-combustion engines, the efficiency of thermal engines as a power source has been improved in line with the development of heat-resistant and pressure-resistant materials, rotating system technology, etc. The recent advancements in power electronics technology such as innovative materials and micro fabrication technology are facilitating the realization of higher density and higher efficiency in the element parts of electric drive systems and the consolidation of functions.

Through these changes, machine power sources will evolve from external- or internal-combustion engines to electric drive systems (or hybrid drive systems), improving environmental performance, maintainability and controllability and reducing the size with consolidated functions and high-speed rotation. The improved compactness and electrification of machine element parts will increase the degree of freedom in machine design, which will transform the shape of the machines themselves. In this type of evolution of power sources, it is important to create innovation by combining old and new technologies. The key is the utilization of existing technological foundations such as rotating machines and etc (**Figure 7**).

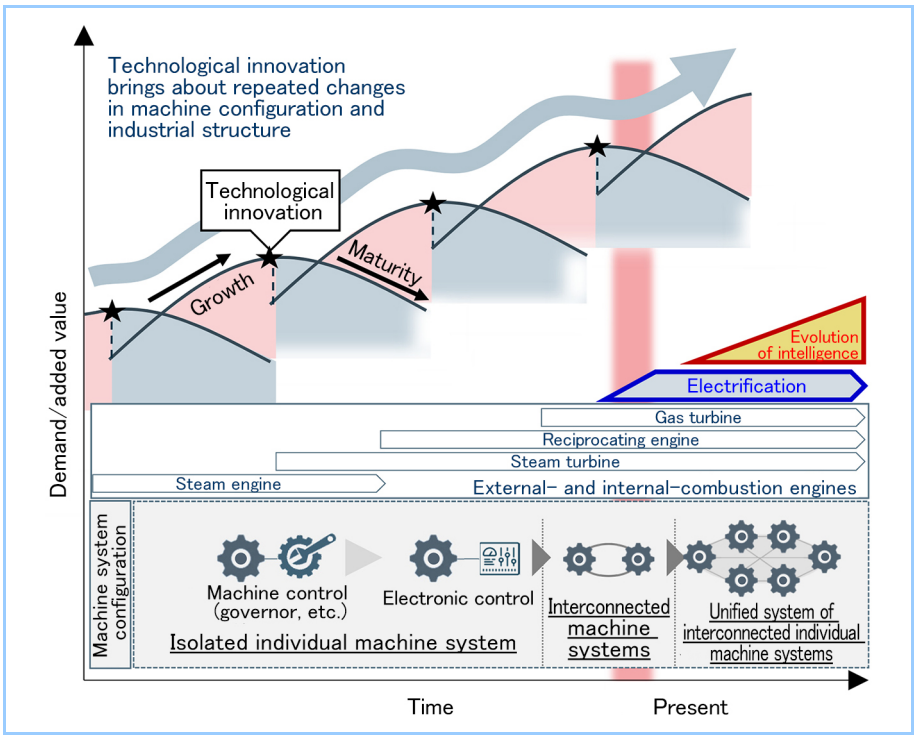

Figure 7 Evolution of power sources and future vision

4. Challenge for innovation through "Hardtech", a new place for co-creation

The changes in the market and technology described so far are taking place at an unprecedented speed and on an unparalleled scale. It is indispensable to take in knowledge from outside the company and funnel it to the creation of innovation. MHI Group has actively taken part in collaboration with universities and other companies. We will further develop such projects to the extent that they can be conducted beyond existing business frameworks or mindsets so that innovative technologies and business ideas can be combined together in a flexible manner. It is also necessary to provide opportunities for the co-creation of innovations.

"Hardtech"[(5)] is pivotal in the evolution of machine systems, and is a combination of digital technological innovations such as AI/IoT and physical technological innovations such as quantum, material design, micro fabrication and biotechnology. For the co-creation of such "Hardtech" innovations, laboratories to build prototypes and test digital applications through trial and error are required. Currently in Japan, however, only a limited number of such laboratories are available to ventures, etc. It is therefore necessary to provide them.

In response to these needs, MHI Group will establish the "Yokohama Hardtech Hub" within the premises of the Yokohama Dockyard & Machinery Works in spring 2020. This place for co-creation will function as a special area that is independent of MHI Group's businesses and be equipped with a laboratory for prototyping and trial-and-error application testing. It will be a place of opportunity, where anyone with enthusiasm, whether from a university, venture or manufacture in Japan or any other countries, can meet with colleagues and where free business activities can be carried out by bringing together the business competencies and technologies of MHI Group and its partner companies for co-creation.

Furthermore, through the co-creation of innovation at the "Yokohama Hardtech Hub", the network between Yokohama City and the rest of the world will be activated, facilitating a contribution to the region and contributing to the cultivation of Japanese "Hardtech" innovators including those in MHI Group (**Figure 8**).

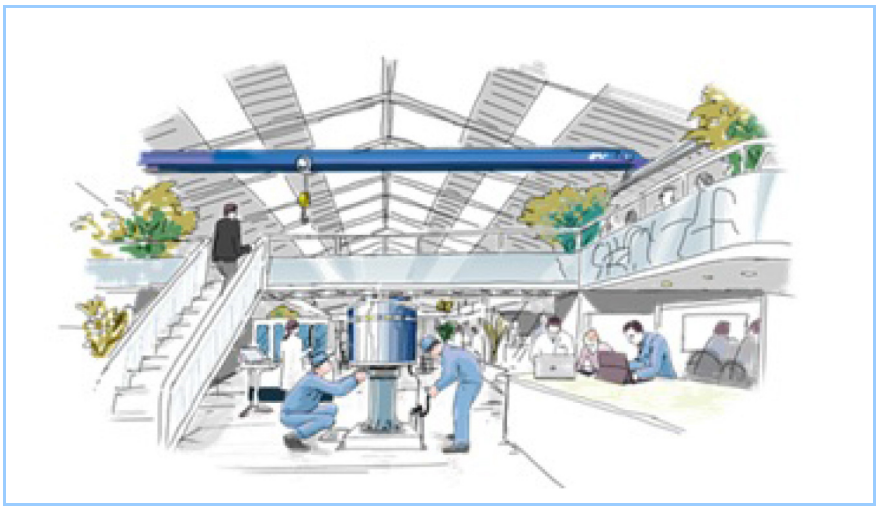

Figure 8 Conceptual image of "Yokohama Hardtech Hub", a place for co-creation

5. Conclusion

Our challenge in MFS will never be finished. By continuing the activities of "Mega Scan", "Shift the Path" and "Technology Scouting" we will identify the needs of future society and foster a corporate culture to meet these needs.

Through our MFS challenge and co-creation of innovation, MHI Group will diligently continue to transform itself so that it can contribute to a future society where humans and machines live together.

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