MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Fundamental Technology Supporting the Energy Transition

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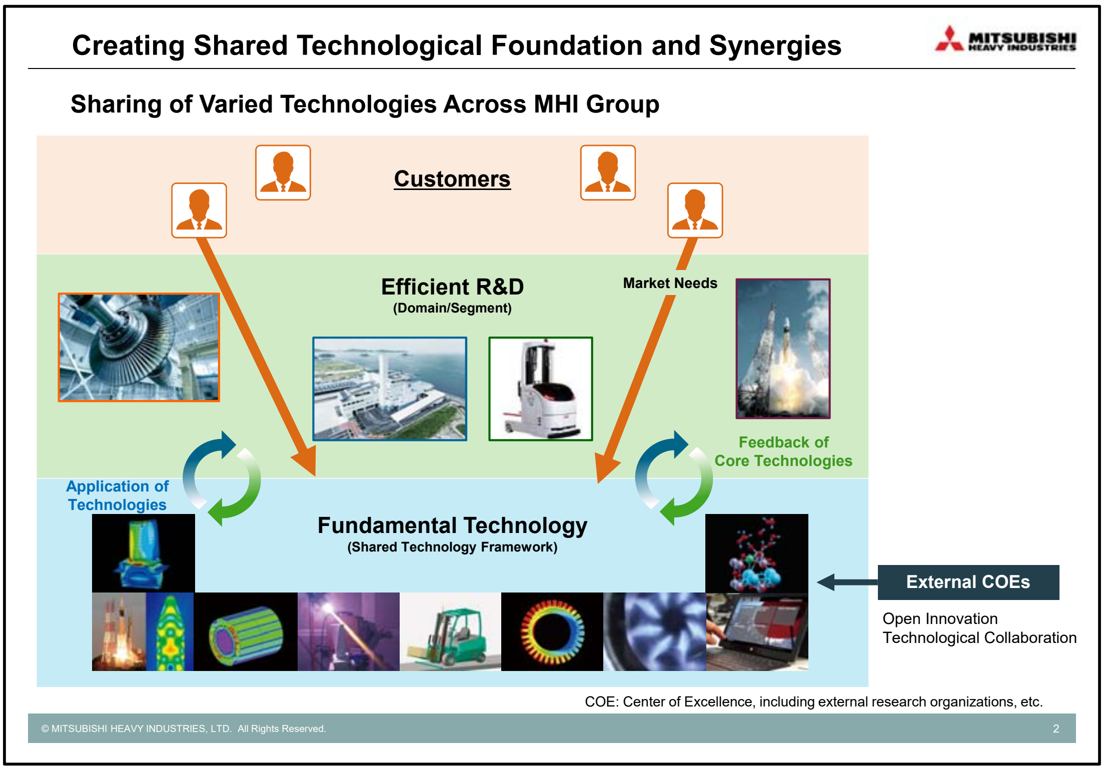
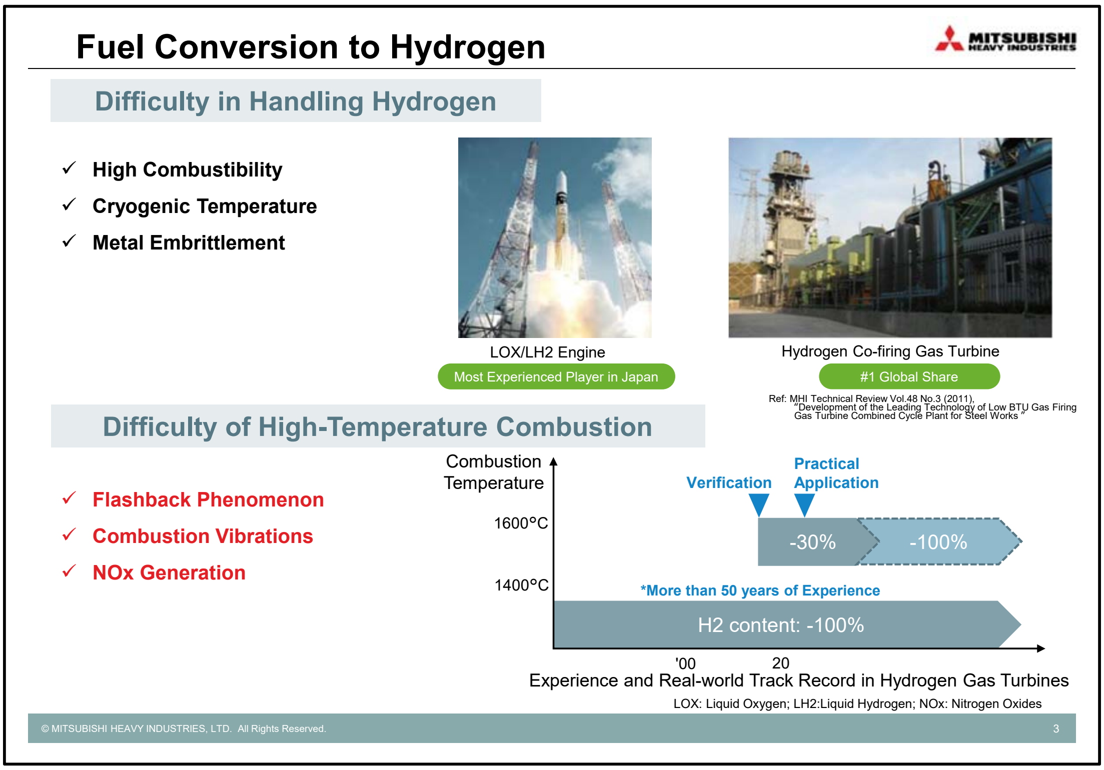
I'm Ito, Chief Technology Officer of MHI.

I will talk about the fundamental technologies supporting the Energy Transition.

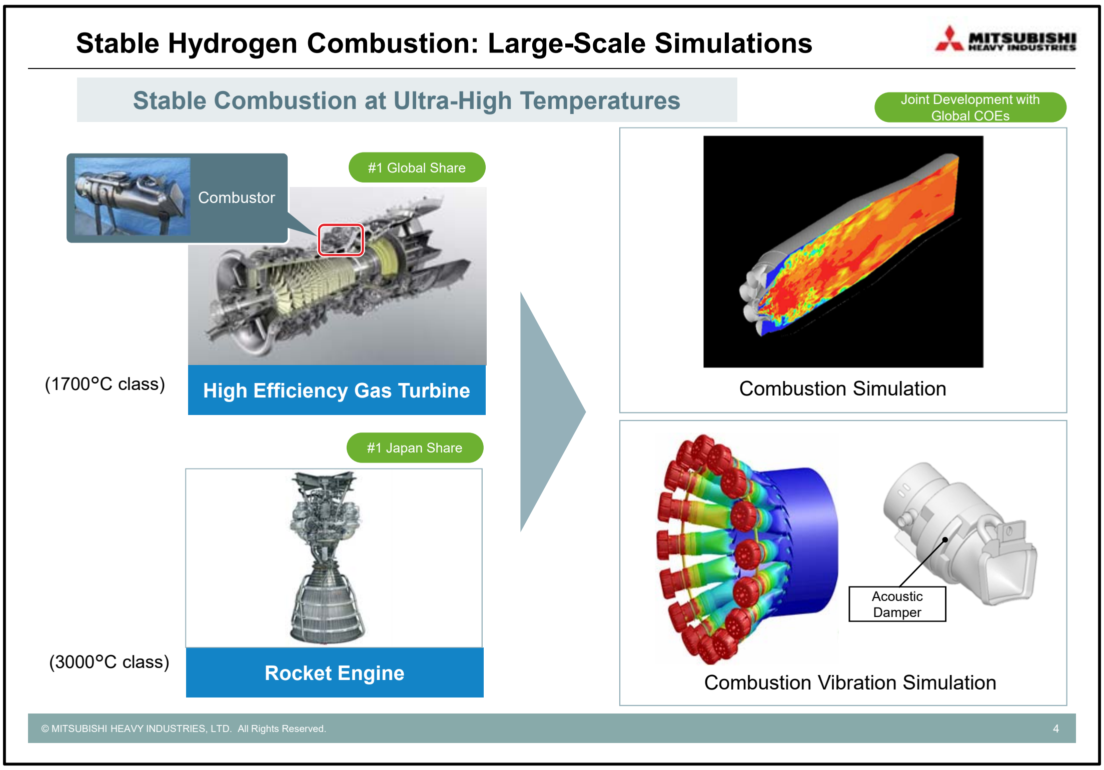


MHI Group creates technological synergies by leveraging the diversity of its products and accumulating and utilizing superior technologies and knowledge in the Shared Technology Framework.
As an example of technological synergies, I will outline conversion to hydrogen in the next slide.



Fuel conversion to hydrogen is an important driver for the energy transition. Hydrogen is a difficult fuel to handle, but MHI Group has many years of experience in its use. First, the fuel for rocket engines is liquid hydrogen. We also have an overwhelming share of the global market for gas turbines powered by by-product gas from steelworks and refineries. This by-product gas fuel contains hydrogen in various proportions, and we have more than 50 years of experience in this area.

We can increase power generation efficiency of gas turbines by increasing combustion temperature. However, when hydrogen is burned at a high temperature, a flashback phenomenon occurs. This causes flames to enter the inside of the machine which causes combustion vibrations that shake the machine violently. If this happens, the machine will break in a few seconds. It is also necessary to reduce NOx emissions, which increase with higher temperature. Our company's gas turbines have been successfully operated with more than 30% hydrogen in the fuel at combustion temperatures exceeding 1600 ℃. The key to achieving this is how to predict and understand combustion conditions.

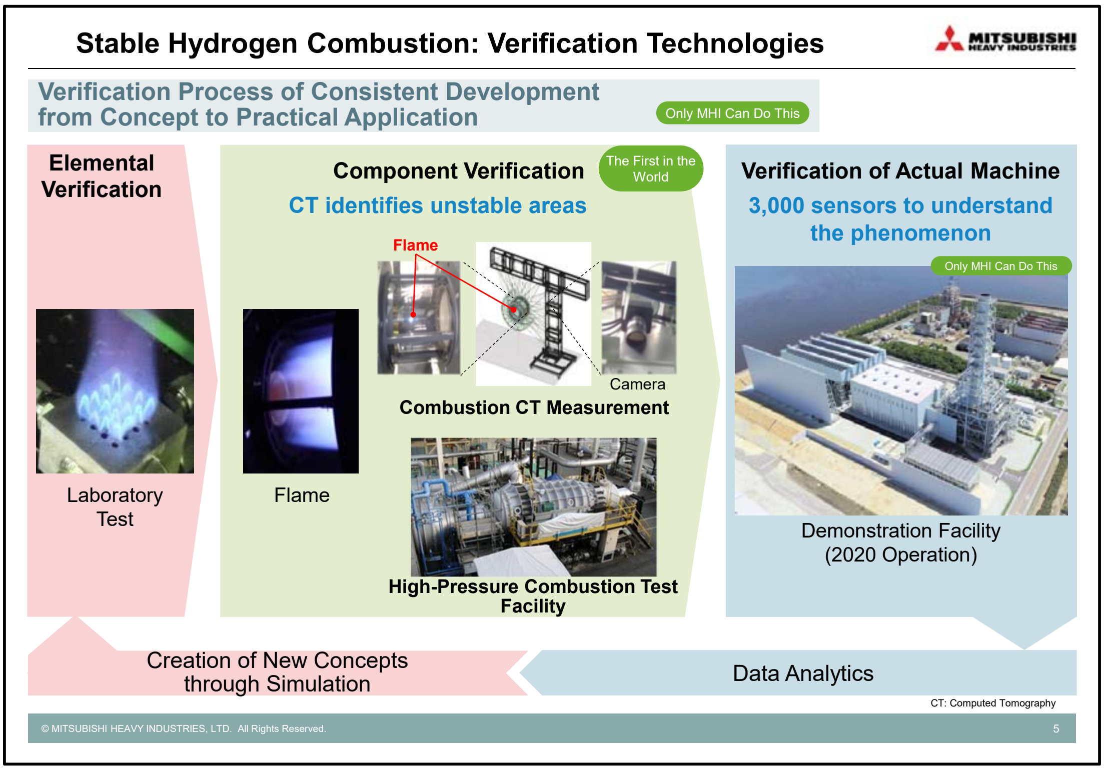


This slide introduces technology for stable combustion of hydrogen at ultra-high temperatures.

Currently, MHI Group's gas turbines are among the most efficient in the world, with the largest global market share as of the first half of 2020. Firstly, this shows combustion prediction technology cultivated in 'Technological development of 1700 ℃ class gas turbine’.

The upper right figure shows an analysis of the combustion condition inside the gas turbine combustor. This analysis uses a technique called Large Eddy Simulation, and uses a proprietary combustion model to analyze dozens of combustion reactions in millionths of a second. Parallel computing is performed using several thousand high-speed computers owned by our Research & Innovation Center. This is a large-scale analysis, equivalent to 1/10 of the power of a K supercomputer.

In the lower right figure, 16 combustors are modeled and combustion vibration is analyzed. In addition, the use of the acoustic damper shown in the figure on the right suppresses combustion vibrations and ensures stable operation even at ultra-high temperatures. This technology was actually applied to the main engine of a rocket, achieving stable hydrogen combustion at around 3000℃.



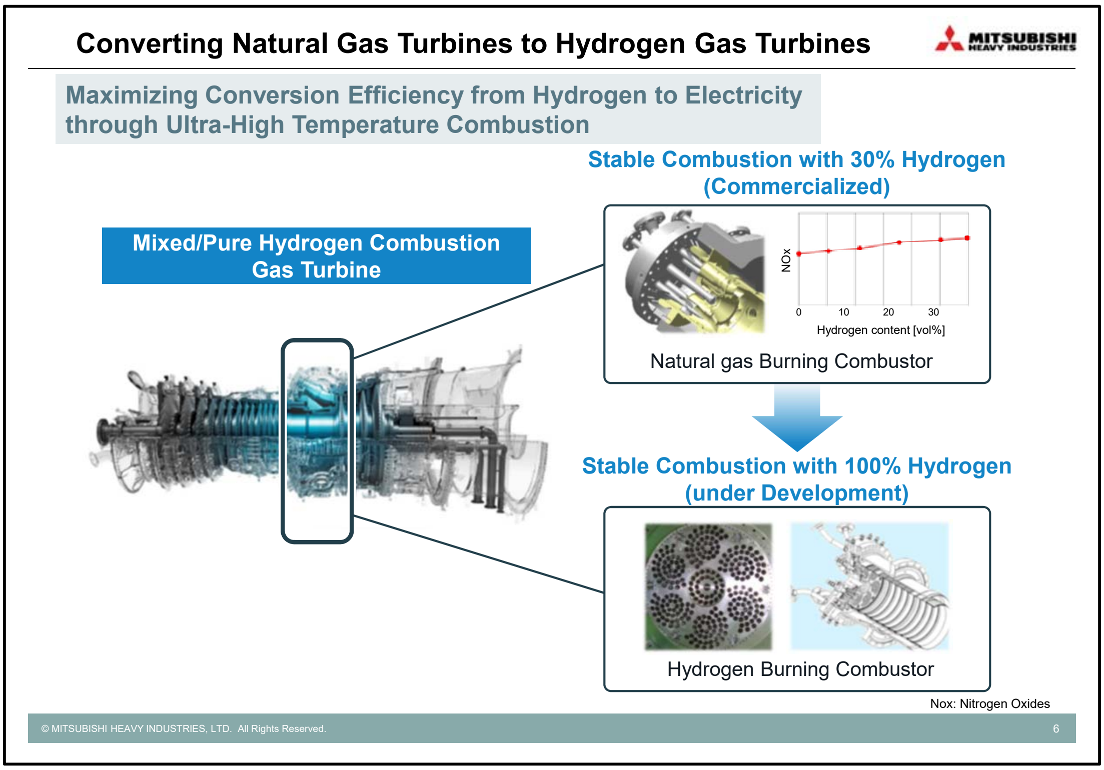
This slide explains the verification process.

Ideas discovered by combustion simulation are validated by laboratory-level element verification.

Next, as a component verification test, a high-pressure combustion test at about 30 bar is conducted. By 3D CT scanning of the light emitted from the flame, the detailed combustion state is ascertained and unstable areas are extracted. The combustion test facility is an improved version of the original combustion test facility for supersonic integral rocket ramjets.

As for the verification of the actual machine, a special sensor with a scale of 3000 points accurately grasps phenomena occurring inside the gas turbine. It will take eight months to prepare. Newly developed parts are incorporated, and the ability can be evaluated under severe commercial operation. For researchers and designers, this is a test without any excuses. The old demonstration power generation facility at the back of the photograph was the first in the world to commercialize 1500 ℃ and 1600 ℃ class gas turbines, completing their 23 year service. While functioning as a verification facility, it achieved high availability of over 99.5% for commercial use.

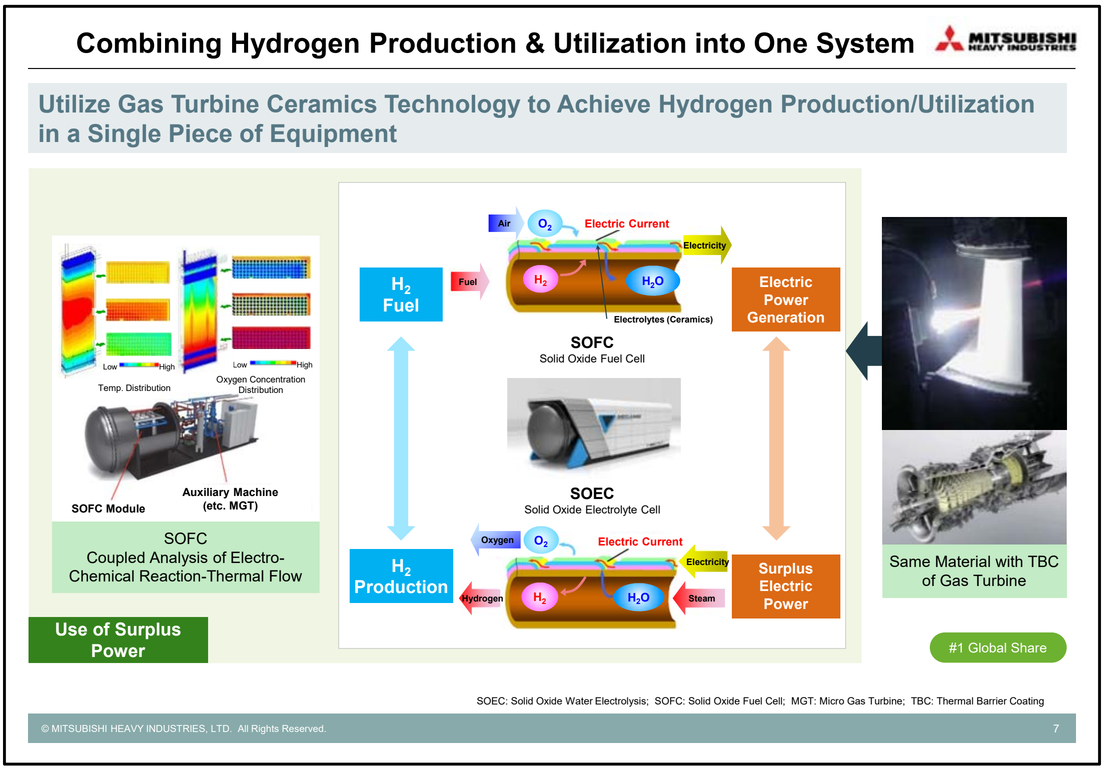
This development process can only be adopted by MHI Group, which has advanced measurement technology and demonstration power generation facilities.



We have confirmed stable combustion of 30% hydrogen mixed fuel at 1600℃ in J-type gas turbine combustors, and that NOx emissions are also within the operational range. The supply of 30% hydrogen fuel is a test limitation and will lead to 100% hydrogen combustion in the future. It can be used in any plant, from the old 900℃ class to the latest 1650℃ class, and can burn hydrogen with almost no hardware change. The 30% co-firing of J-type gas turbines is equivalent to 200,000kW, which corresponds to one million hydrogen powered vehicles.

You might have a question about how to procure a large amount of hydrogen. The following is an example of a solution proposed by MHI Group.

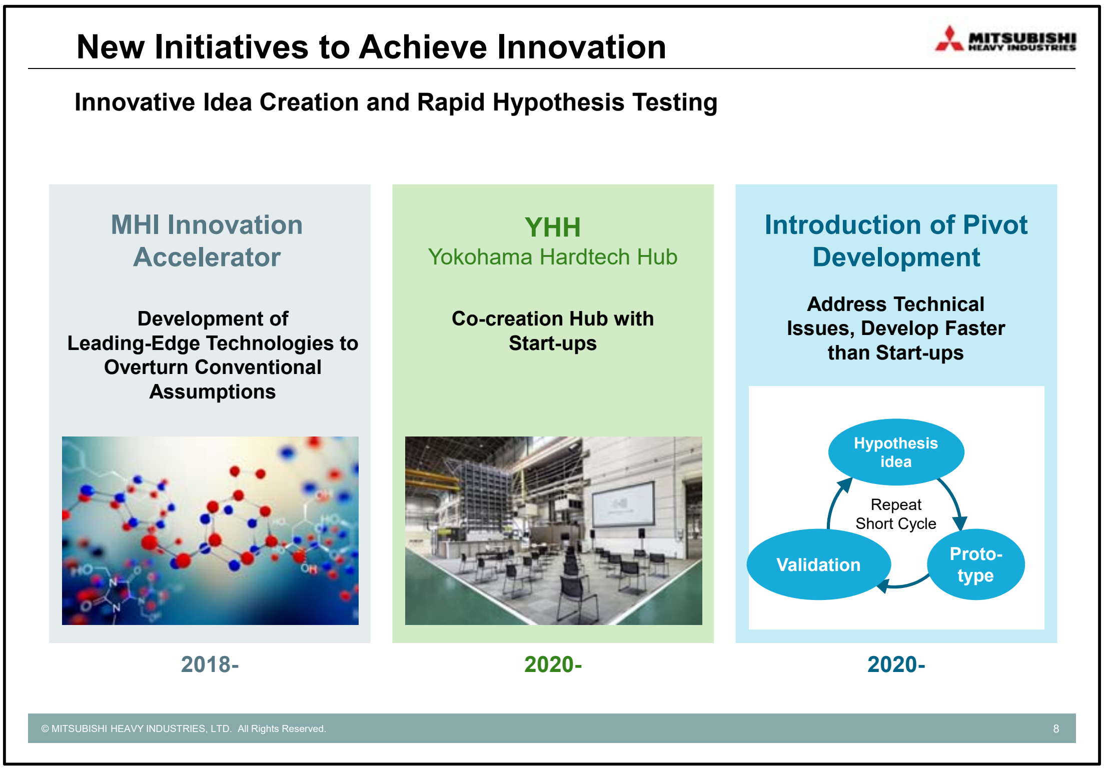
Surplus electricity from renewable energy, which will increase in the future, will be sent back to existing power plants using existing grids, and hydrogen will be produced in the plants.
If it is mixed with conventional fuel in a power plant, hydrogen co-combustion becomes possible immediately.
It does not require the liquefaction or transportation of hydrogen, so it can be said to be the most economical way to popularize hydrogen.
This is an energy transition that makes the most of existing infrastructure.



This slide describes SOFC, a distributed generator.

SOFC is a device that generates electricity directly from hydrogen. SOFC is already used by many customers in combination with micro gas turbines. For practical application, the analysis technology coupling chemical reaction, electricity, and thermal flow is applied. Electrolyte ceramics are made of the same material as gas turbine thermal barrier coating.

Although not well known, SOFC can also produce hydrogen. With a single device, hydrogen can be produced using surplus electricity from renewable energy, and it can be returned to electricity by itself. It can be said to be a form of distributed power generation facility after the introduction of large amounts of renewable energy.

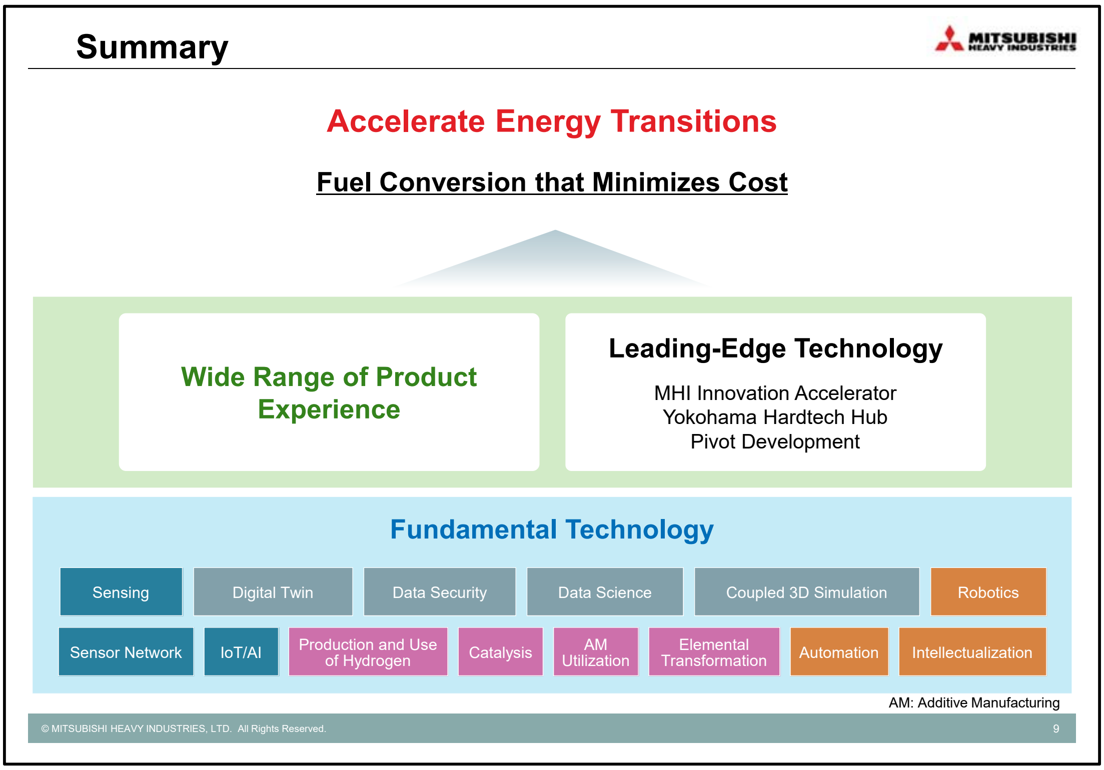


The Shared Technology Framework has launched three new initiatives to realize innovation while creating such technological synergies.

First is the Innovation Promotion Research Institute. From new research areas such as quantum mechanics, we will develop leading-edge technologies that will overturn existing assumptions. It is the research and development of innovative technologies with dreams that have a major impact on society. By collaborating with internal and external researchers and working from the basic stage, we will accelerate future practical applications.

Next, we have established YHH, Yokohama Hardtech Hub, as a space for co-creation with start-ups. It is equipped with the infrastructure for test production and trial and error of implementation, and the research is mainly focused on hard technology. Several start-ups have already started their activities. We will accelerate commercialization by adding our Group’s technologies, facilities, and human resources, and we will acquire the ability to think as an innovator.

The third is the introduction of pivot development to broaden horizons. We have introduced a new system in which researchers can develop and test their own hypotheses based on their own ideas. The conditions are that you can express your ideas in your own words, and that you break down technological issues into smaller pieces and work on them at a speed that surpasses start-ups. Within a few months, we launched more than 300 new themes. In this process, failures are also accumulated as good hypothesis testing data.



I will wrap up.

In the Shared Technology Framework, there are fundamental technologies in many fields which I was not able to touch upon. Combining these with a wide range of product experiences creates technological synergies.

We also want to accelerate the energy transition by developing leading-edge technologies through three new initiatives.

This concludes my presentation.

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