

## Strengthening Our Technological Foundations (CTO Message)



We will lay the groundwork for future growth by reforming MHI Group’s technological foundations.

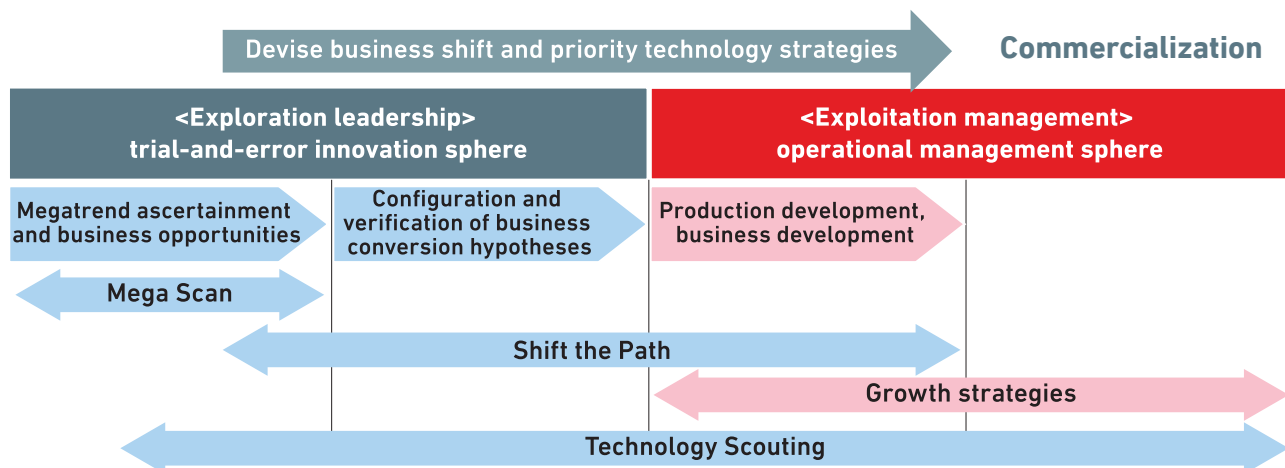
Executive Vice President/CTO  
Eisaku Ito

### Exploration and Evolution in Pursuit of Innovation

MHI Group has been contributing to societal progress since its inception by deploying machinery systems integral to social infrastructure. Recent years have been marked by increasingly complex societal challenges (e.g., SDGs), diversification of people’s values and tech-

nological innovation, including advances in digitalization, functional materials and biotech. Meanwhile, COVID-19 has changed people’s behavior and is driving nebulous, discontinuous changes in needs and values with respect to social infrastructure.

- ▶ Deployment of Growth Strategy from MHI FUTURE STREAM  
(blue: led by the Shared Technology Framework, red: led by our business divisions)



Against such a backdrop, we continue to carry out MHI FUTURE STREAM activities to gain a big-picture grasp of political, economic, societal and technological changes within MHI Group's business environment from a medium- to long-term perspective and to formulate optimal business strategies based on multiple scenarios. MHI FUTURE STREAM comprises three steps. The first is Mega Scan, where we formulate medium- to long-term change scenarios. The second is Shift the Path, where we hunt for business opportunities based on innovation hypotheses around markets and technology. The third is Technology Scouting, where we seek out highly impactful disruptive technologies and collaborations with external partners. We are exploring new directions in which to shift our businesses to capitalize on promising megatrends.

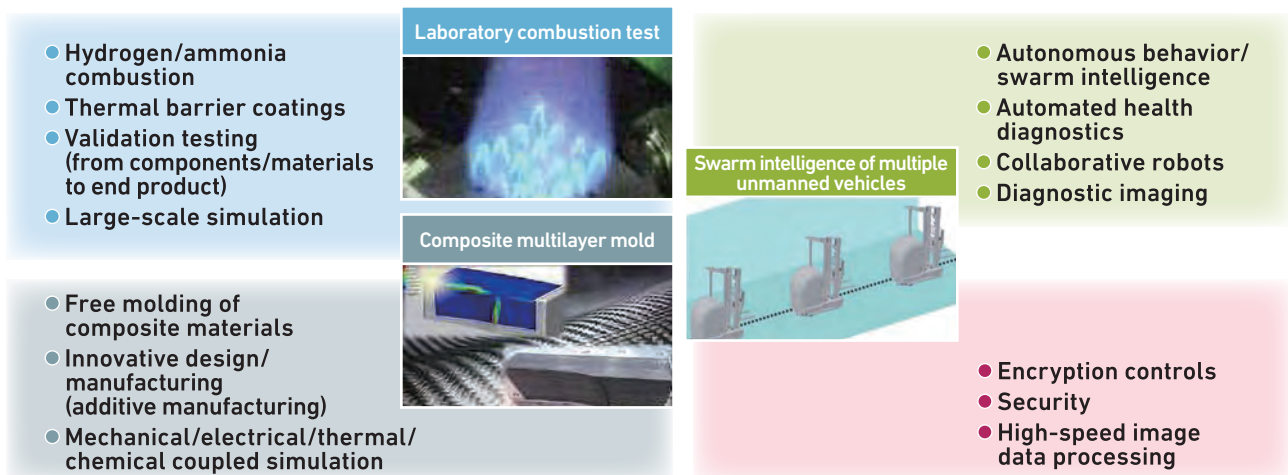
One idea generated by MHI FUTURE STREAM activities is evolution of machinery systems. We are focusing on electrification and smartification in particular. We intend to also contribute to energy transition as one of our growth strategies. We expect the transition to drive CO<sub>2</sub> reduction through improvement in machinery's efficiency and yield alternatives to the internal combustion engine.

On the smartification front, we are developing not only AI technologies, including application of deep learning to image-processing technologies we have long been cultivating, but also technologies that add new value, including machinery capable of collaborating with humans by virtue of autonomous control and advanced swarm control. We believe we can apply such technologies to multiple new businesses in the mobility domain, the focus of another of our growth strategies.

Meanwhile, a cluster of several core technologies has emerged. It includes autonomous vehicles, electrification, thermal management and new materials. By applying these technologies, we can create new value and add value to existing products. We will innovate by distilling internal and external expertise and flexibly combining innovative technologies and business ideas.

Innovations we intend to explore and exploit include not only creation of new businesses and products but also improvements in existing products' performance and increases in competitiveness through cost reductions. We will help realize a safe, secure society by ensuring essential safety and reliability as a manufacturer.

## ► Exploitation of Basic Technologies and Development of New Functionalities



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### New Innovation Initiatives

As an innovation initiative, we opened Yokohama Hardtech Hub (YHH) in 2020 as a co-creation space to bring startup companies' ideas to fruition. It is our second such site alongside Mitsubishi Innovation Accelerator LLC, established in 2018 to glean new insights from leading-edge technologies and research. Incessant innovation in response to changing societal needs requires exploration through prototyping and testing based on hypotheses formulated knowledgeably and insightfully from a big-picture and/or long-term perspective. We will utilize YHH to actively practice such exploratory innovation. YHH signed up seven startups as tenants in its initial fiscal year. We plan to keep expanding and developing YHH as a space that attracts talent and technologies across diverse disciplines. In December 2020, YHH hosted a co-creation event, the theme of which was "The Reality of Manufacturing and Value of Co-creation in the Space Sector." The event featured discussions with academics and entrepreneurs on the challenges and rewards of manufacturing in the space sector. We will continue to build a community of collaborators through such events.

While gaining more external collaborators through such outreach, we of course have to reform our own thought processes and behavior patterns with respect to innovation. Toward this end, we adopted an R&D model called Pivot Development in 2020 under the banner of developing products faster than startups. An iterative process of formulating and testing hypotheses based on

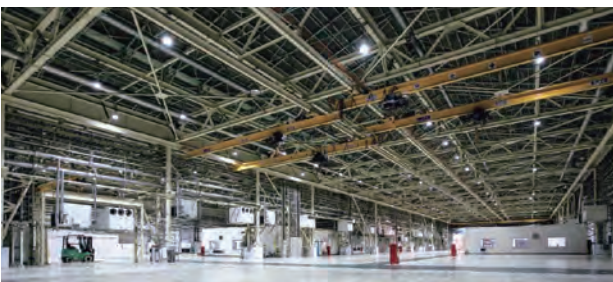
researchers' free-flowing ideas is essential to discovering and concretely applying new knowledge. One effective way to iterate efficiently is to deconstruct the problem in question into sub-problems, formulate hypotheses as granularly as possible and condense the process into a short timeframe. This approach enables researchers to pivot on the fly in response to testing outcomes. It is also predicated on acceptance of the possibility of failure. Breaking a problem down into small steps and pivoting whenever warranted increases the success rate relative to tackling a big problem as an all-or-nothing proposition. We fielded over 500 ideas and launched many projects during the Pivot Development program's initial fiscal year. Around 25% of the ideas that completed the iterative process either reached the prototype stage or were incorporated into an SBU's development plan.

One such idea is that unmanned vehicles deployable on land, at sea, in the sky and in space could be developed by applying technologies amassed in the development of automated forklifts and autonomous robots. Another idea is that with MHI Group being a global leader in CO<sub>2</sub> capture, we might be able to turn captured carbon into an environmentally friendly, value-additive product if we were able to convert it into a valuable input for other products instead of storing it underground.



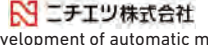



By thus developing new technologies and combining them with existing core technologies, we will bring MHI Group's growth strategies to fruition.

#### ▶ Spacious prototyping/testing environment

- 20,000 m<sup>2</sup> of total floor area
- Equipped with power supplies, compressed air, cranes, HVAC, WiFi



#### ▶ Seven occupants (as of April 2021)

 Integrated digital production of wood structures	 Design, testing and production of space equipment
 Development of automatic mold changers for injection molding	 Vibration testing services
 Materials development aided by computer science and machine learning	 Development and installation of battery control systems
<b>Tsubasa Science</b> Development of coating materials for, e.g., semiconductor production equipment components	

## Example: Technological Synergies in Fuel-Switching to Hydrogen

We are developing technology to support energy transition in the aim of realizing a carbon-neutral society by 2050.

MHI Group is pursuing carbon neutrality through various initiatives to shrink existing businesses' carbon footprints, launch new carbon-free businesses, generate power from hydrogen and develop energy storage solutions. In developing decarbonization technologies, we generate synergies by capitalizing on our products' diversity and amassing knowledge and superior technologies and sharing them cross-organizationally. One such synergy involves fuel-switching to hydrogen, a key energy transition tactic.

Non-CO<sub>2</sub>-emitting fuels currently seen as promising include hydrogen and ammonia. MHI Group has a long history of using hydrogen despite its being a difficult-to-handle fuel. Rocket engines burn liquid hydrogen as fuel. Steel mills and petroleum refineries have been using gas turbines fueled by byproduct gases that include hydrogen in varying proportions for over 50 years. We command a dominant share of the global market for such turbines. Gas turbines' power generation efficiency can be increased by raising their combustion temperature. In

2018, we succeeded in developing a hydrogen gas turbine that operates stably at a combustion temperature in excess of 1,600°C while burning fuel with hydrogen content of 30% or more. To do so, we used large-scale combustion simulation technology. Applying this simulation technology to rockets' main engines, we achieved stable hydrogen combustion at temperatures in the vicinity of 3,000°C.

Additionally the validity of ideas generated by combustion simulations is confirmed by verification test under actual equipment pressure condition after laboratory combustion tests. The facilities used to conduct these combustion tests were designed for supersonic ramjet engines. The tests yield synergies in addition to advanced measurement technology. Using an MHI Group demonstration power plant where production gas turbines are tested, we plan to test a hydrogen ecosystem inclusive of hydrogen production facilities. Development is expected to accelerate further.

In sum, the combination of our diverse basic technologies and broad product experience is generating various synergies and driving innovation.

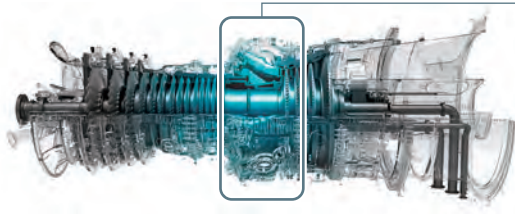


LOX/LH2 engine  
Most launches in Japan

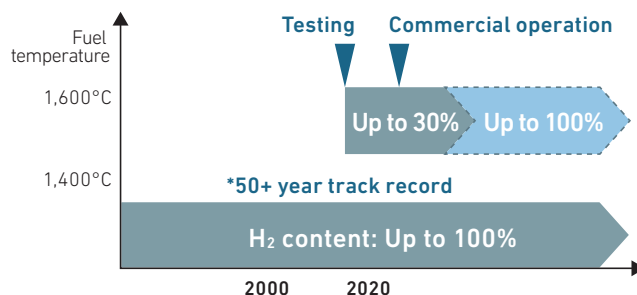
Hydrogen co-firing gas turbine  
Global market share leader

Source: MHI Technical Review Vol. 48 No. 3 (2011), Development of Leading Technology for a Low-BTU Gas-firing Gas-turbine Combined-cycle Plant at a Steelworks

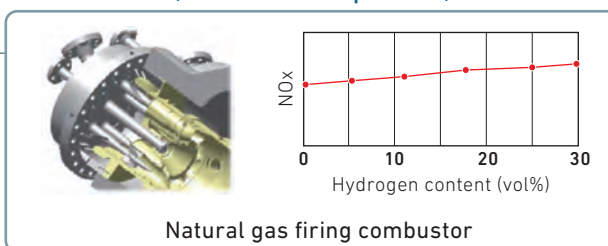
### ▶ Hydrogen co-firing/100% hydrogen firing gas turbine



### ▶ Gas turbine combustor Hydrogen fuel experiment



### Stable combustion with 30% hydrogen content (in commercial operation)



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### Example: Machinery Systems' DX-Driven Evolution

As another example, we are developing technologies in new spheres such as mobility through integration of digital technologies into machinery systems.

MHI Group has long been commercially applying AI technologies, most notably deep learning, to use cases such as automated operation of plant products. By combining digital, communications and control technologies, all of which have advanced dramatically in recent years, we interlink multiple machines to enable them to optimally operate like a single machine. In HVAC (Heating, Ventilation, and Air Conditioning) and logistics as well, both of which we have designated as growth areas, we are smartifying, automating and substantially upgrading product performance.

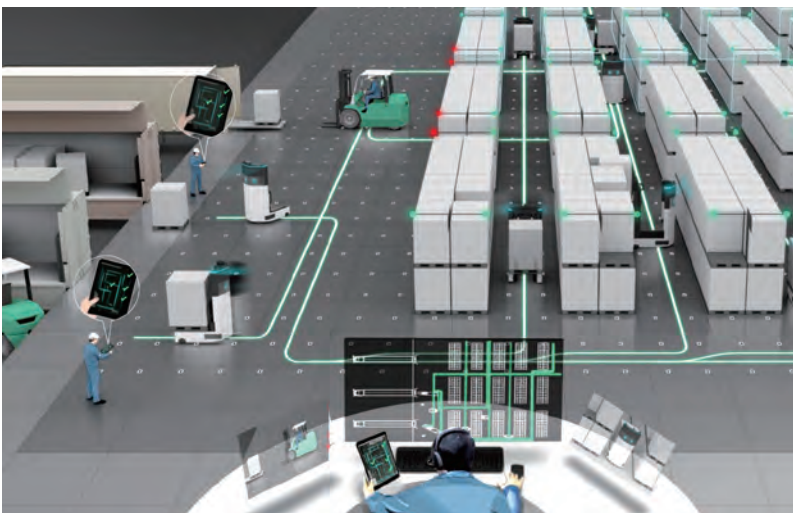
We have proposed  $\Sigma$  SynX as an automation and smartification solution concept applicable to all MHI Group products. One application of  $\Sigma$  SynX is the SynX-Vehicle, a new concept automated guided forklift (AGF). While based on a conventional forklift, the SynX-Vehicle is more compact. We minimized its footprint to enable warehouses to increase storage space by reducing aisle width. It also features improved stability and a new rotation method to speed up workflow. Additionally, it has a display panel that visually communicates with nearby

workers (e.g., by signaling it will yield at an intersection) to increase safety and productivity. This technology was developed using the aforementioned Pivot Development model. The SynX-Vehicle's development was completed in a mere six months by a team of mostly young engineers.

Going forward, we will apply control technologies that efficiently coordinate multiple unmanned vehicles, technologies that detect humans and objects and/or human interface technologies to facilitate communication between humans and machines. Such technologies will enable us to provide logistics solutions that flexibly adapt to the specific workplace in which they are deployed and ensure high productivity and safety through collaboration between humans and machines. In cold-chain logistics as well, we plan to create added value by combining chillers with thermal management technologies.

Technologies that reliably and efficiently operate complex machinery and plants are one of our strengths. While supplying machinery that leverages this strength as a core competency, we are creating new value and successively rolling out innovative components by smartifying and automating machinery. We continue to evolve as a machinery systems maker that delivers innovation to society.

#### ▶ $\Sigma$ SynX-powered AGF



## Addressing Societal Challenges

As I mentioned at the outset, societal challenges are becoming increasingly complex while people's values are rapidly diversifying. Many hurdles must be surmounted to realize a carbon-neutral society by 2050. People will still require mobility while goods will need to be transported efficiently. MHI Group possesses the experience, track record and capabilities to provide solutions in response to such diverse needs for environmental remedies and circular-society building in pursuit of a sustainable society.

Recent advances in AI and digital technologies are driving automation, autonomization and operational optimization of machinery. Capitalizing on such trends, we will upgrade transportation safety and convenience, improve logistic efficiency and increase social systems' productivity. We will also leverage big data and leading-edge data analytics technology to provide innovative solutions that protect everyday infrastructure against natural disasters and other threats.

Meanwhile, with all types of devices now being connected to networks, server security risk has become a threat to safety and peace of mind. We will protect cus-

tomers from invisible threats by combining MHI Group solutions with security technologies developed for defense and other applications.

One of MHI Group's strengths is over 500 broad product lines ranging from defense hardware and plants to air conditioners, including products of differing scale and user-ship and machinery used on land, at sea, in the sky and in space. Every MHI product embeds a host of top-level technologies. By generating synergies with newly acquired key technologies, we are able to offer solutions that add novel value and contribute to resolving societal problems.

We will build broad networks through MHI FUTURE STREAM activities, sensitively detect changes and formulate foresighted strategies. Toward this end, we have embarked on new initiatives over the past year, including establishing YHH and adopting the Pivot Development model of radical technological innovation. While forging ahead with MHI FUTURE STREAM, we will continue to evolve as a machinery system manufacturer that delivers innovation to society. I am highly confident MHI Group can make great strides toward fulfillment of its growth strategy.

### ► MHI Group's vision of the safe, secure society it aims to help realize



- People living sustainably in harmony with the environment and technology.
- Resilience that keeps people safe and secure even during emergencies.

MHI Group will reliably support both.