SPECTRA

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MITSUBISHI HEAVY INDUSTRIES | MISSION NET ZERO

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

OUR MISSION IS NET ZERO

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CHAPTER 1.

CARBON NEUTRAL WORLD

MHI'S CHAIRMAN MIYANAGA ON HUMAN CAPITALISM: BUILDING TRUST ON THE ROAD TO NET ZERO

By Shunichi Miyanaga / 2022-02-14

Most nations today recognize both the importance and the urgency of the battle against global warming; but there are still significant differences on how best to achieve net zero greenhouse gas emissions and how to share the cost of doing so. In the polarized world we unfortunately live in, this creates a lot of room for conflict—conflict between cultures, geographies and even generations. That, in turn, leads to an erosion of trust which not only slows our progress on fighting climate change but spills over into other social and political issues.

The corporate sector has a vital role to play in tackling and, ultimately, helping to solve this issue. Companies are sometimes more agile than national governments and are often close to local communities with a deep understanding of their needs. At the same time, they are often able to marshal greater resources than those communities can do independently and are experienced at achieving goals and targets.

Take global warming itself. While many countries have set laudable goals, with more than 130 nations promising to reach net zero emissions by 2050 or even earlier, few have set out detailed roadmaps on how to get there. If you look at the four most realistic pathways for carbon dioxide (CO_2) emissions as set out by the International Energy Agency (IEA), then even with all the new commitments made at last November's COP26 summit in Glasgow, global temperatures will rise by at least 1.8°C above pre-industrial levels by

"The private sector is taking practical steps on the road to net zero, focusing on proven technologies and mobilizing the capital needed to scale these up"

2050. If we do not implement those promises, then temperatures will rise by 2-3°C, with potentially disastrous consequences for our planet.

CORPORATES TAKE THE INITIATIVE

By contrast, the private sector is taking smaller but eminently practical steps on the road to net zero, focusing on proven technologies and mobilizing the capital needed to scale these up. Three areas that are a priority for the IEA and also attracted a lot of attention at last November's COP26 summit are:

• decarbonizing existing infrastructure, such as helping utilities switch from coal and oil to cleaner natural gas and eventually zero-carbon fuels like ammonia and hydrogen;

• scaling up carbon dioxide capture, utilization and storage (CCUS) technologies and building a value chain for CO_2 from capture to transport, storage and utilization in industry;

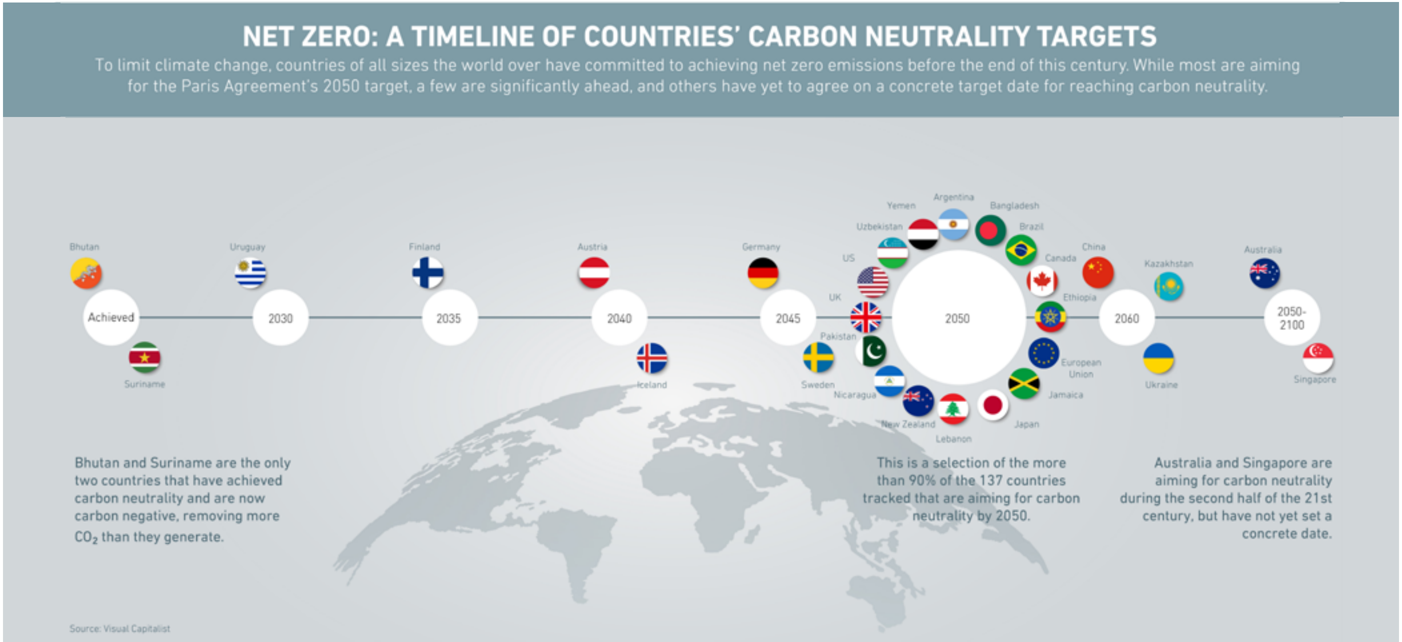
• and building a similar ecosystem for hydrogen that also encompasses production, transport, storage and multiple applications in energy, industry and long-distance transportation.

Every day, we invest in research and development in these areas. We work closely with our customers to anticipate their needs; and we encourage our suppliers to invest alongside us. It helps that many of the technologies we focus on are well-established and make use of similar components to those in thermal power equipment.

We also collaborate with companies we would once have regarded only as competitors, as well as with start-ups, industry organizations and academic institutions. We understand the need for partnership to achieve results and the need for openness to create trust. While we need to keep some intellectual property secret in order to achieve a commercial return as a company, we are sharing more and more of our technology. A good example is the recent public testing of our new proprietary CO_2 solvent at a third-party facility in Norway.

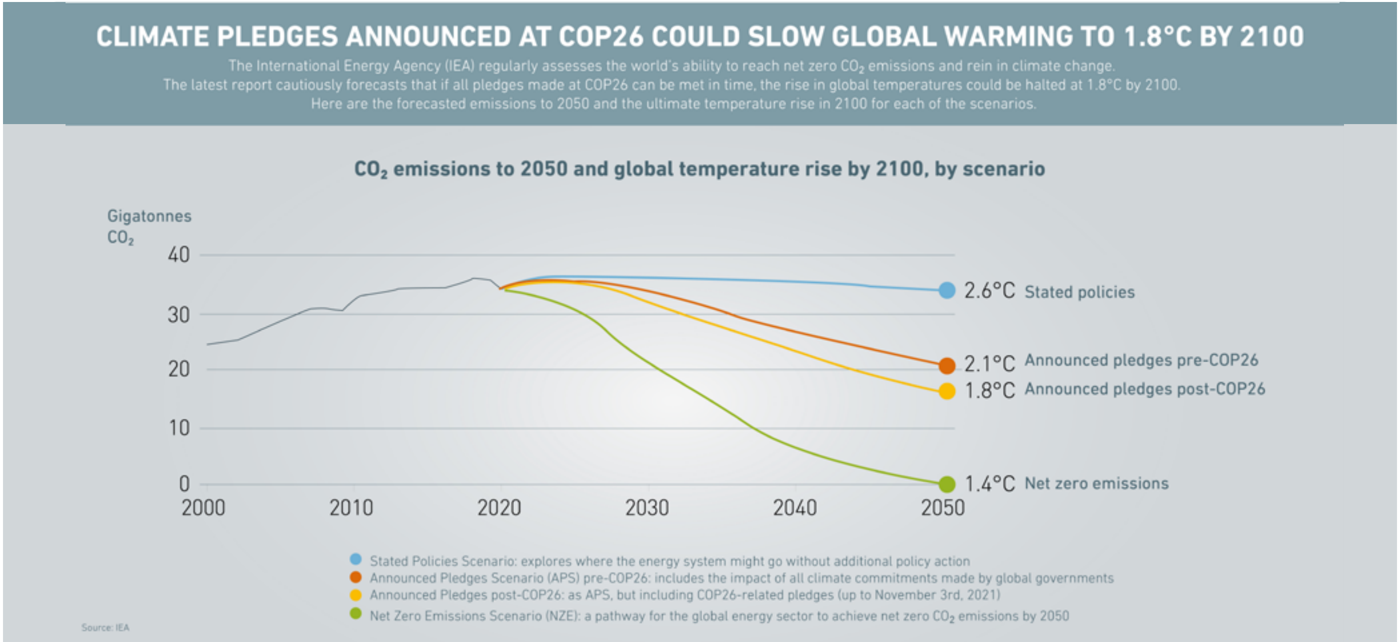
CAPITALISM WITH A HUMAN FACE

This emphasis on openness, collaboration and trust is not just about solving concrete engineering challenges more quickly but also about setting an example. I believe that companies are deeply rooted in society. They must work for the overall happiness and progress of society—and do so consciously and explicitly rather than just blindly pursuing profit. Not only do corporations need to listen to the views of their diverse stakeholders; they also need to understand that they can—and do—influence the behavior of customers, suppliers, employees, investors and the community at large—for better or worse. It is a two-way street.



This is a heavy responsibility and the true meaning of what is often labeled "ESG" or "sustainability". I prefer to call it 'human capitalism' and it is not a new idea, nor an idea born only in Japan. But it has been out of favor until recently, during a period when the Anglo-Saxon variety of capitalism dominated developed economies; and I do believe that Japanese philosophy and attitudes are a very good foundation for human capitalism. In Japan, we have traditionally prized stability and harmony even if the price has been less rapid growth. In the past, this was only possible in relatively homogenous societies that maintained a certain degree of isolation: think of the stability of Edo-period Japan compared to, say, the chaotic fall of Rome. The wonderful thing in today's interconnected world, however, is that we can strive for human capitalism on a global scale. And we can do so across the generations. In particular, we should pay more attention to the needs of the young, whose natural anxiety about the state of the world has led many to become disaffected or simply disconnected. We should not only think of ourselves. After all, humans are mortal but society is immortal.

One thing we must all do, right now—and by "we" I mean the very people who come to Davos—is to communicate better. We need to inform all stakeholders about what we have already



done, about our plans for the future and how these will affect them. We must not shy away from difficult questions and should accept sensible criticism and adapt. Increased openness will restore trust, allowing faster progress toward our common goals. It is a pretty simple virtuous circle. All participants including our company should intend to play their part as responsible citizens to create a better world. ■

"I do believe that Japanese philosophy and attitudes are a very good foundation for human capitalism. In Japan we have traditionally prized stability and harmony even if the price has been less rapid growth"

MHI'S EMEA CEO HOSOMI ON COP26: REALISM, PRAGMATISM AND A NEW SENSE OF URGENCY

By Kentaro Hosomi / 2021-12-21

The recent COP26 climate summit may have lacked the grand political bargains of earlier meetings such as Paris in 2015, but it made up for that by achieving steady and pragmatic progress, industry by industry and company by company. As leader of the delegation from Mitsubishi Heavy Industries (MHI) Group, my colleagues and I met with executives and stakeholders from a wide range of sectors and everywhere we sensed both a new urgency to decarbonize and a willingness to set realistic goals and take measured steps to hit these targets. For these reasons, I judge the Glasgow conference to have been a success.

TECHNOLOGIES ALREADY EXIST

One clear difference at this meeting, in my view, was the focus on existing technology. How can we make the best use of it right now, rather than relying on future breakthrough inventions to bail out the world. In particular, there was huge interest in carbon capture and hydrogen and how to scale them in a timeframe that will allow us to keep global temperatures from rising by less than 2°C and, ideally, by no more than 1.5°C from pre-industrial times.

There was much discussion of the investment needed and the huge challenges that have to be overcome to build end-to-end value chains for CO_2 and hydrogen from production (or capture) across transportation and storage to end use. However, we heard far less talk about these technologies being counter-productive and even "evil" because they would prolong our reliance on fossil fuels. There was also frank acknowledgement that in order to maintain acceptable levels of economic growth, the world will have to rely on bridging fuels such as natural gas for years to come.

Such pragmatism is encouraging since it gives companies, industries and those who finance them the visibility and certainty to plan and invest in the energy transition at the required scale—and, if I am honest, the industry level is where much of the progress is being made currently. In each of the three areas I have highlighted—decarbonizing existing infrastructure, carbon capture and hydrogen—MHI, as an experienced technology provider, has a lot to contribute. Early versions of our hydrogen co-firing gas turbines are already available; we are the world market leader in CCUS technology with a roughly 70% share; and we are investing in a hydrogen ecosystem that spans green hydrogen production in Australia; ships that will transport it in the form of ammonia; and storage, for example, in salt caverns in the US.

JAPAN'S EVOLVING ROLE IN CCUS AND HYDROGEN

It is worth noting in this context that the models of our hydrogen-firing turbines and CCUS equipment that were displayed in the Japanese pavilion in the COP26 Blue Zone in Glasgow attracted large crowds. In fact, the Japanese pavilion, as one of the only ones with models of hardware on display, was one of the most popular destinations throughout the summit—perhaps another indication of delegates' desire for pragmatism over political pronouncements.

Another highlight for me was the attention being paid to industrial clusters as a way of efficiently decarbonizing high-emission areas that combine power generation and various industries. England's East Coast Cluster, in which MHI and its partner Drax as well as Triton Power are heavily involved, received timely UK government support just days before the conference and featured prominently in MHI's CCUS-themed panel discussion.

For hydrogen, meanwhile, it is becoming clear to me that while the EU will be its main end market, at least initially, a lot of the most cost-effective production of blue and/or green hydrogen is likely to flourish around its fringe—like the Middle East and North Africa with their ideal conditions for generating renewable power—as well as in Norway and the UK with their prospective sites for carbon storage. Countries from these regions made high-profile announcements of their hydrogen ambitions at Glasgow and MHI can play a role in helping them with production, storage and exports.

AN ACHIEVABLE PATH TOWARDS A CARBON NEUTRAL WORLD

Meanwhile, I learned a new expression, "just transition", used by those emphasizing the need to make the energy transition inclusive and equitable. Ironically, this term is now being used not only by delegates from lesser-developed countries but also by ones from European nations hard hit by the recent spike in energy prices. However, the larger lesson we must learn is that as companies, industries and governments work together to fight climate change, we must make sure that our solutions are not only clean but also reliable and affordable for all.

The difficulties in the global race to limit global warming are real. But all of us at MHI understand the need to make steady progress and look forward to continuing the dialogue in 2022 at the Davos meetings, followed by COP27, which will be held at Sharm El-Sheikh in Egypt. ■

"How can we make use of existing technologies right now, rather than relying on future breakthrough inventions to bail out the world?"

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STORE, SCALE AND APPLY: HARNESSING HYDROGEN'S FULL POTENTIAL

By Professor Emmanouil Kakaras / 2021-10-26

Hydrogen has been used by humans for more than a century and its potential as a clean energy source has been recognized for many years. But historically it has always disappointed expectations, most recently in the early 2000s. Things have fundamentally changed in the last five years, however, as technology has developed to the point where hydrogen can now be developed, at scale, not only as a carbon-free energy carrier but also as a storage vector.

This was the missing factor. Now that storage is part of the equation, we can unleash the full potential of this versatile gas to achieve—over time—a complete decarbonization of our energy system and our hard-to-abate industrial and transport sectors. That is why the current wave of "hydrogen hype" is justified and why I truly believe it will be possible for the world to achieve net zero carbon emissions by 2050.

The challenges remain considerable, of course. But now that the political will exists—over 30 countries have released hydrogen roadmaps, $70 billion of public funding has been committed and the industry has announced over 200 projects to invest some $300 billion through 2030, notes McKinsey—the roadmap we need to follow is relatively straightforward.

BUILDING DEMAND AND A HYDROGEN VALUE CHAIN

The first step is to build demand through new applications. Today's annual global hydrogen production of around 80 megatonnes—just 4% of the energy mix, according to the International Energy Agency (IEA)—is mostly used in a few industrial processes, such as refining and petrochemicals.

We must greatly expand hydrogen's utilization, for example, by replacing natural gas in steelmaking; building fuel-cell trucks, buses and trains for long-distance transport; blending it into the gas pipelines and boilers that heat buildings; and using it to store renewable electricity.

At the same time, we must replace "gray" hydrogen—which contributes to carbon emissions because it is produced from natural gas and which constitutes the bulk of today's production, with carbon-free versions: either "blue" (or "turquoise") hydrogen, where these emissions are captured at source; or "green" hydrogen, which is produced via electrolysis powered by renewable power. Cleaning up today's hydrogen output is low-hanging fruit.

More difficult and capital intensive will be building a complete hydrogen value chain, but this is something we must tackle in the coming decade. We can start with large projects, such as the Hamburg Green Hydrogen Hub in which Mitsubishi Heavy Industries (MHI) Group is involved, and which plans to decarbonize the city's port, shipping infrastructure and local gas pipelines with green hydrogen. Such clusters can be supplied either by onsite hydrogen production or be connected to pipeline networks, say from the North Sea or North Africa in the case of Europe. Alternatively, hydrogen can be shipped in from low-cost production centers like Australia or the Middle East, perhaps in the form of ammonia, via "zero-carbon" carriers powered by synthetic fuels.

Meanwhile, the rapid deployment of solar and wind power means some countries now have a surplus of renewable energy currently being curtailed in most cases, which can be stored as green hydrogen, for example in salt caverns, as MHI Group is planning to do in Utah in the US. Hydrogen allows much longer-term storage than batteries, so the electricity can be fed back into the grid when needed. It is true that the conversion (or "round tripping") of electricity into hydrogen and back again results in substantial energy losses. But critics forget that this surplus energy that renewables produce intermittently would otherwise be simply wasted.

SCALING UP AND CUTTING COSTS

It is also true that carbon-free hydrogen is still too expensive and reducing the cost from the current \$4-5/kg in Europe to a competitive \$1.50/kg will be hard—and in other countries like Japan, it is even more costly. Supportive regulation and perhaps even subsidies can take us some of the way, but we have to take care not to create affordability issues for end consumers. Market mechanisms, like contracts for differences and open competition against other energy sources will be much more effective. But the main and most obvious solution is scale. We must scale up—and massively so—all of the steps I have described above and this will quickly bring prices down.

This is why MHI Group welcomes the UK's recent pragmatic and market-based hydrogen policy, as right now we need every kilogram of carbon-free hydrogen that we can produce at competitive prices. So, prioritizing cheaper blue hydrogen makes a lot of sense, as long as it is coupled with coherent management of the resulting carbon dioxide. Again, I would point to the UK, as well as the US, Norway and some others as countries where the storage and/or industrial use of CO_2 is being actively promoted.

My group at MHI is working on both carbon-based products, such as synthetic carbon-free fuels, for use in shipping and aviation and on improving the efficiency of converting hydrogen into other carriers, such as ammonia. As someone who has conducted research and lectures on mechanical engineering, I feel privileged to witness research results turning to practice at a great speed. I am excited that we are able to attract bright young engineers and motivate them to use modern skills in electrochemistry and artificial intelligence for the new energy business. It gives me real hope that we will achieve the 100% decarbonization that the world so badly needs. ■

"Prioritizing cheaper blue hydrogen makes a lot of sense, as long as it is coupled with coherent management of the resulting carbon dioxide"

CCUS, TRANSPORT AND TRADE: CREATING A HOLISTIC CARBON MARKET

By Makoto Susaki / 2021-09-30

In order to hit its 2050 net zero target for carbon dioxide emissions, the world will have to virtually eliminate the 40 gigatonnes of CO_2 that it currently pours into the atmosphere every year. Even if the significant growth of renewables and other carbon-free energy sources continues, we redouble our efforts to reduce consumption and also improve energy efficiency, a sizeable gap will remain: an annual 4.3-13 gigatonnes of CO_2 will somehow have to be removed from the atmosphere to reach a carbon neutral world.

CCUS AS A KEY PILLAR AND THE MAJOR BARRIER TO ITS ADOPTION

There are currently only two technologies capable of both reducing and removing emissions. The first is carbon dioxide capture, utilization and storage (CCUS), which the International Energy Agency (IEA) has acknowledged as a key pillar in the energy transition. This process traps more than 90% of the CO_2 in the flue gas emitted by power stations or hard-to-abate industrial plants—and the carbon can then be stored underground or used by industry. But despite its many advantages, there are currently only 26 commercial-scale CCUS operations in place globally—14 of them installed by Mitsubishi Heavy Industries (MHI) Group—capturing just 40 megatonnes of carbon annually.

The major barrier to greater adoption, as the IEA recognizes, is cost. As global leaders, with a 70% market share, MHI is working hard to bring the average price of CCUS down from \$50-70/tonne of CO_2 to around \$30/tonne through cheaper technology, economies of scale and applying it to more industries, such as liquefied natural gas (LNG). This is working: there are almost 40 new CCUS projects under development, including the world's largest at Drax Power Station in the UK, which will remove 9 megatonnes of carbon per year on its own. But we will ultimately need to capture 200 times today's volumes and that requires government subsidies, such as the 45Q tax credit in the US, a sufficiently robust worldwide carbon price and — ultimately — willingness by consumers to pay a "green premium"

for products produced with clean technology.

DAC'S POSSIBILITY

The second technology that can help remove emissions is direct air capture (DAC). This will be desperately needed in the decades to come since even if we capture CO_2 from all our existing industrial and energy infrastructure, it will not be enough. However, DAC is not a mature technology yet and while we are working to perfect it, the current cost of $150-200/tonne of CO_2 at the very minimum is prohibitive.

Meanwhile, it is also critical to think about what to do with the CO_2 once captured. Fortunately, industrial applications, for example using carbon to produce electrofuels or cement, are proliferating, making it increasingly valuable. Large-scale storage sites, such as depleted oil reservoirs and sub-sea aquifers, also exist. But such storage will need to be paid for, as will the network of pipelines, ships and trucks to get the carbon from where it is captured to where it can be used or sequestered.

MORE THAN AN EQUIPMENT SUPPLIER, CREATING A VALUE CHAIN

We at MHI intend to be involved in all aspects of this carbon value chain. Apart from the CCUS equipment, we supply compressors and pumps and are studying construction of a liquefied CO_2 (LCO_2) carrier to cover long distances at low cost. However, we want to be more than an equipment supplier. As we build out the physical carbon network, we are simultaneously working with IBM on a digital carbon network that we call CO_2NNEX. The ultimate aim is to create a marketplace for trading carbon, with MHI Group bringing buyers and sellers together and taking a commission. Think of it as offering "CaaS"—CO_2 as a service—to our customers, be they utilities selling captured CO_2, oil companies offering storage, or industrial users wishing to purchase carbon black.

We are confident that one, or more, such global carbon markets will evolve in the next five to 10 years since we are not the only ones with this idea. We will need partners of course, but we already have IBM on the digital side and can find people with the right commercial and trading background. Japan, which is interested in carbon capture and utilization (CCU), and the UK, which is investing heavily in carbon capture and storage (CCS), are promising launch markets.

The carbon business is one of MHI's core pillars and by evolving it creatively we can ensure a future both for our company and the world. ■

HOW THE US BUILDS A MODEL FOR A SUCCESSFUL ENERGY TRANSITION

By Takajiro "Tak" Ishikawa / 2021-09-07

I have lived and worked in the US and Canada for almost 30 years. During that time, there have been multiple false starts in our efforts to reduce energy consumption and fight climate change. Today, however, I am optimistic: the challenges remain monumental, but the world is beginning to develop a working model of how to accomplish the energy transition—and nowhere are the factors for success coming together more quickly than in America.

THREE FACTORS WILL MAKE THE ENERGY TRANSITION SUCCEED

The first is technology. In years past, people believed that "clean tech" was quick and asset-light, like developing software for an app. The investment community has since learned that it is multifaceted and involves hardware, and lots of it. With that comes the need to design plants, test, operate and scale them. All of this is difficult, expensive and time-consuming. But Silicon Valley attracts the brightest minds on the planet, and these (young) entrepreneurs and academics are increasingly focusing on environmental technology.

In part, they are doing so because of the second factor: growing social acceptance—pressure even—that we need to mitigate climate risks. In the financial world, this is being expressed in the momentum behind ESG (environmental, social and governance) investing. As of the end of the first quarter of 2021, close to $2 trillion was invested globally in more than 4,500 sustainable funds, according to Dimensional, a US asset manager. Corporations that do not have a measurable target to address ESG or a clear path to tackling climate change will eventually be left behind by capital markets. Coupled with government initiatives as seen in the US, Japan, South Korea, the EU and elsewhere, the behavioral changes we are seeing today are here to stay.

Third, the money is there this time. On top of the trillions flowing into ESG mutual funds, venture capitalists are backing early-stage private companies: $17 billion was invested in US climate tech in 2020, according to Bloomberg. The American entrepreneurial ecosystem in conjunction with the US tax system, the collaboration between academia and its ability to attract the best talent from around the globe is the greatest system on earth when it comes to bridging minds and capital.

THE ROLE OF THE US GOVERNMENT IN ENHANCING THE ENERGY TRANSITION

The US public sector, though often much derided, continues to play a significant role. Production tax credits (PTCs), first implemented in 1992, explain why America now has 122 gigawatts of wind power, the equivalent of more than 100 nuclear power stations. The 45Q tax incentive expanded by the Trump administration has increased awareness of carbon capture technologies. It is expected that President Biden will maintain or increase these incentives and add a sizeable infrastructure package of perhaps $2 trillion, which will further boost demand for low-carbon solutions.

> **“Technology is moving rapidly, and we don’t know what will emerge as winners in 2050”**

Mitsubishi Heavy Industries (MHI) Group is ideally placed to take advantage of this favorable backdrop. As US utilities switch from coal to natural gas and potentially to hydrogen, we can offer them our gas turbines, among the most efficient on the market and with the capability to add hydrogen to the fuel mix—we have already achieved 30% validation and aim to validate 100% by 2025. We are also world leaders in carbon capture, which we have proved at scale at a US coalfired power plant in Texas and are in the Front End Engineering Design (FEED) phase to apply this technology to gas turbines being deployed in liquid natural gas (LNG) production.

COLLABORATION IS ALWAYS KEY

Technology is moving rapidly, and we don’t know what will emerge as winners in 2050. With investor dollars far exceeding private companies’ R&D budgets, I tasked my team at MHI-America to initiate dialogues with leading venture capitalists and start-ups engaged in cutting-edge climate technology. In early 2020, we secured capital from MHI headquarters to embark on developing these investment opportunities. In the latter half of 2020, with the assistance of our colleagues in Tokyo, we closed four deals in six months: investing in start-ups that specialize in alternative methods to produce green hydrogen, green ammonia and electrofuels.

Our aim is to work closely with these start-ups to develop, design, optimize and scale their technology, and perhaps identify clients that can derive benefits. If we succeed, we will have aided in transforming MHI from a manufacturer of CO_2-emitting equipment into the “enabler” of the energy transition.

While we will always remain a technology-driven firm, adopting an asset-light business model that relies more on service revenues, licensing and royalty income from technology (ours and our partners’), would allow us to operate in a more nimble and agile manner.

I see a promising future for MHI. The energy transition is hard work. It is “hard tech” and will require a strong balance sheet to reach fruition. Over 150 years ago, MHI was the enabler of Japan’s industrial revolution. As we look to the future, MHI is uniquely positioned to enable the energy transition and move the world forward. ■

THE ENERGY TRANSITION IN APAC: ONE STEP AT A TIME

By Yoshiyuki Hanasawa / 2021-06-29

The Asia-Pacific (APAC) region as we define it at Mitsubishi Heavy Industries (MHI) Group is a vast region, spanning countries from Australia and New Zealand all the way to India. Even excluding China and our Japanese home market, this is a region of more than 2 billion people with widely varying levels of economic development. They are responsible for around a fifth of global greenhouse gas emissions—which in some countries are still growing rapidly.

PHASED APPROACHES MAKE AN APAC ENERGY TRANSITION

It therefore makes no sense to talk about a one-size-fits-all approach when it comes to the energy transition in APAC. I find it more helpful to group APAC nations into three broad categories. India, Indonesia and most members of the Association of Southeast Asian Nations (ASEAN) countries are at the very beginning of this journey and still rely heavily on thermal power from oil and coal. Their best strategy is to focus on increasing energy efficiency and reducing consumption. They should also start the switch from coal to gas—and particularly liquefied natural gas (LNG)—by creating a gas value chain, including transportation, storage and stable end demand.

Where countries have domestic renewable resources, such as Indonesia and the Philippines, that is a bonus: MHI recently announced it will enlarge a geothermal power plant in the Philippines, which has plentiful sources of underground heat. Realistically, though, renewable energy is still too expensive for these emerging economies to develop wind and solar generation on a large scale.

Second-stage countries, principally Singapore and Malaysia, have already made the transition to gas: in Singapore it accounts for 95% of electricity production. They should now be setting aggressive targets for renewables and, indeed, they are doing so. Big technology firms, whose data centers Singapore wants to host, insist that such centers are powered entirely by green energy. But geography is not always on our side. As a small island, Singapore has limited land available to cover with solar panels or wind turbines. MHI is working with the government and local firms such as Keppel Data Centres to explore producing or importing alternative fuels like hydrogen and ammonia. However, these may initially have to be “blue”, which means their production will involve some carbon emissions, rather than being entirely green.

AUSTRALIA IS WELL ADVANCED IN THE ENERGY TRANSITION

Finally, there is Australia, which is rich in natural resources like coal and gas and also rich in renewables, with plentiful wind, sun and land. The country is already well advanced in its energy transition and aims to become a major exporter of green energy, targeting markets like Japan, South Korea and Singapore—even Europe. Our task, as I see it, is to provide technical and financial support to accelerate these efforts. A good example is the large-scale development of an “aerotropolis” in western Sydney, sponsored by the New South Wales government. MHI is one of only a handful of Japanese founding partners for this huge project, which includes a second airport for Sydney, commercial and residential development, a new transport system and potentially a new research facility—all powered by clean energy.

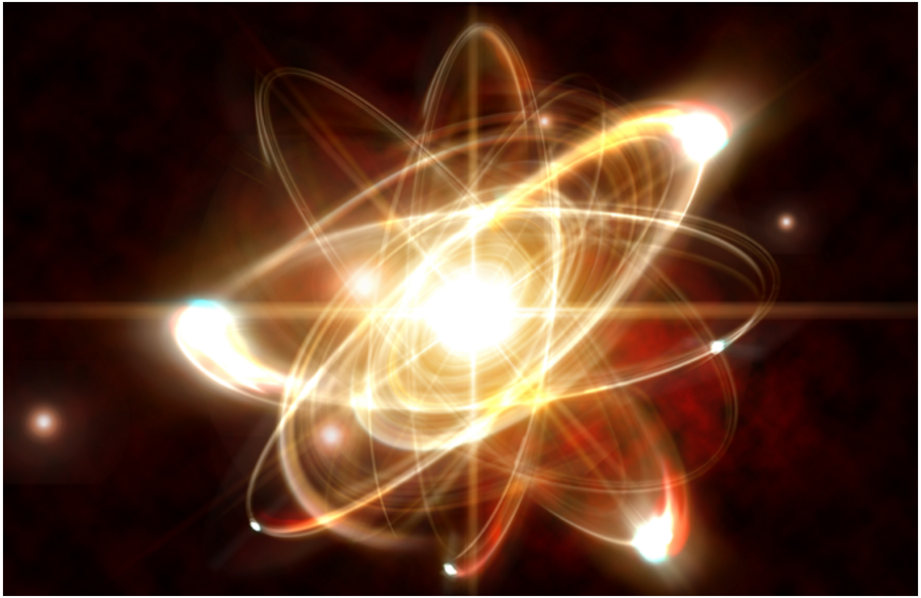
FOCUSING ON THE BIG PICTURE AND ALL STAKEHOLDERS

Separately, we are investing in and providing expertise as well as equipment to H2U, a start-up in South Australia that plans to produce and eventually export green ammonia and green hydrogen. What attracted us to this company was its sound business plan that is based on gradually building production and finding local customers first before starting to ship overseas. One reason, perhaps, that H2U was willing to work with us is that I visited the firm in the midst of the pandemic, sat down with local aboriginal leaders to hear their concerns and went to a local rugby match!

It is this ability to collaborate with many different partners, to establish personal relationships and to understand the needs of all stakeholders that is the core of my role and, I believe, the reason for MHI’s success in the APAC region. ■

“It makes no sense to talk about a one-size-fits-all approach when it comes to the energy transition in APAC”

CAN NUCLEAR FUSION GIVE US UNLIMITED EMISSIONS-FREE ENERGY?



By Andrea Willige / 2020-06-11

Nuclear fusion has long been heralded as the future of energy. Replicating the process that powers the sun promises an endless supply of renewable energy without greenhouse gases. The concept has fascinated science fiction writers—but has eluded scientists for decades.

There are now multiple projects entering critical phases, however. The timing could not be better as fusion could be a trump card in the world's quest for emission-free energy.

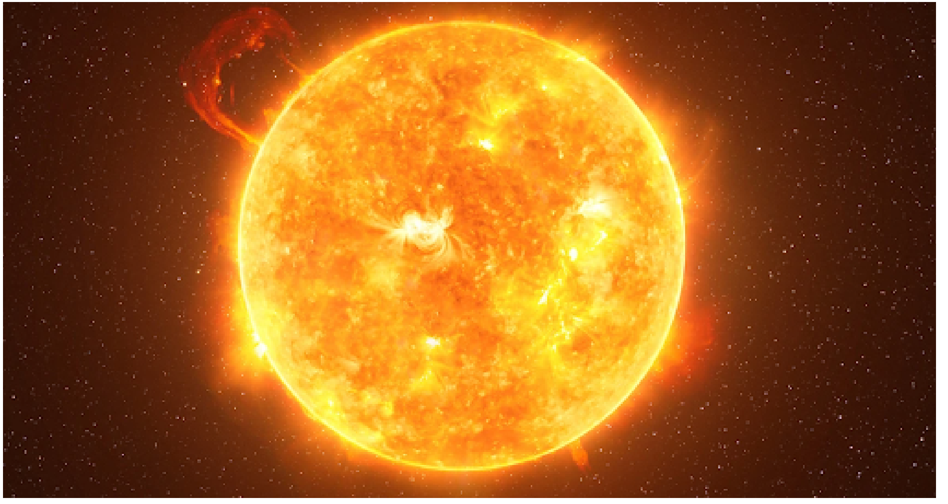
BRINGING THE SUN TO EARTH

Fusion may sound futuristic, but it's older than our planet. Life itself could not have developed without it.

After the Big Bang, hydrogen clouds consolidated to form stars like our sun, and these stars are powered by fusion. In a star's core, gravitational forces and temperatures of 15 million degrees Celsius create a super-heated gas or plasma, which causes hydrogen atoms to collide with each other and merge to form a heavier element, helium. In this process, copious amounts of energy are released—mainly in the form of light and heat.

Recreating the conditions at the core of our sun is a challenge, to say the least, which explains why fusion energy has been something of a holy grail for science and engineering.

As Makoto Sugimoto, Director for the ITER fusion project at Japan's National Institutes for Quantum and Radiological Science and



Technology (QST), explains: “Nuclear fusion is very complicated both scientifically and technically —it’s a long journey. Not only do plasma physics have to be studied—because the behavior of plasmas is complicated—but you also have the engineering challenges to satisfy the required temperature, density, and confinement time to achieve fusion.”

Despite its inherent difficulty, fusion as an energy source remains a tantalizing prospect, he says. “Because a fusion reactor stops when there is a fault or error, the fusion reaction is inherently safe.”

Not only that, he adds, but it does not produce long-lived nuclear waste, and fusion fuels are virtually inexhaustible—they can be found or distilled from seawater.

“Although fusion is technically not a renewable energy, it’s essentially the same thing.”

DEVELOPING TECHNOLOGIES

Fusion reactors use two hydrogen isotopes, deuterium and tritium, which have proved to be the most effective in laboratory settings. That means they produce the highest energy gain at the “lowest” temperatures.

> **“Making fusion a reality required the development of leading-edge technologies in the fields of superconductivity, high vacuum, and cryogenics”**

Deuterium can be readily extracted from seawater and the infrastructure already exists to do so, as deuterium is used in numerous scientific and industrial settings. Tritium can be created through contact with lithium, which can also be extracted from seawater. The walls inside a fusion reactor are lined with a “blanket” containing lithium to “breed” tritium on demand as the fusion process unfolds.

The demands on the fusion reactor—effectively bringing the energy of the sun to Earth—are extremely high. A lot of scientific advances had to come together to bring us closer to delivering on this tall order.

“Making fusion a reality required the development of leading-edge technologies in the fields of superconductivity, high vacuum, and cryogenics,” Makoto Sugimoto at QST points out.

This is also the reason why fusion has been elusive, with many of the enabling technologies only becoming available in small increments over time.

ENTER THE TOKAMAK

It's surprising then, that the most widely used form of a fusion reactor—called a tokamak—was developed as long ago as the 1950s and 60s and it lives up to its name.

The tokamak is a doughnut-shaped (toroidal) vacuum chamber that uses extremely strong electromagnetic fields to maintain and confine the super-heated plasma created by the deuterium-tritium fuel mix—at temperatures of between 150 and 300 million degrees Celsius.

The world's largest tokamak is currently under construction in southern France as part of the ITER fusion research and engineering project. To establish its containment field requires an array of powerful magnets. These include 18 toroidal field coils weighing over 300 each and about 17 meters in height. Designed for Japan's ITER member, QST, by Mitsubishi Heavy Industries (MHI) Group, they are said to be the largest and most powerful superconductive magnets ever created. As Masahiko Inoue, project director of ITER at MHI, explains, the magnets will be subjected to thousands of tonnes of electromagnetic loads and must withstand immense forces and extreme temperature differences.

ITER temperatures will range from about 150 million degrees Celsius—10 times the temperature in the core of the sun—down to nearly absolute zero. This has required a new, extremely hard type of stainless steel to be developed, and a new technique to weld structures up to 40 centimeters thick.

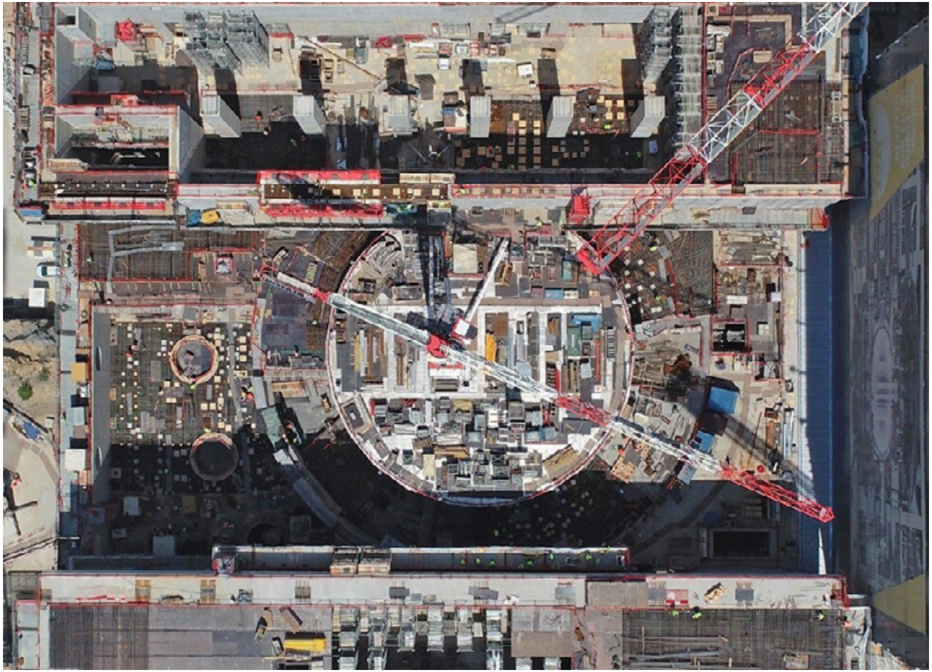
And these high demands are also reflected in huge proportions of the tokamak's superstructure and its supporting infrastructure, which illustrates the challenge that such a project poses. The tokamak complex at ITER will be a 400,000 tonne building, 80 meters tall, 120 meters long and 80 meters wide. Seven stories high, the structure will also include more than 30 plant systems needed for the fusion reactor's operation.

CURRENT PROJECTS

ITER is planning for "first plasma" in December 2025—some 40 years after the idea of an international joint experiment was first launched.

ITER will take over from the Joint European Torus (Jet) in the UK, which is part of the 28-country Eurofusion research initiative, whose tokamak has been operating since 1983.

Fusion projects using tokamak technology are



underway around the world, including in the US and China. The new Chinese Fusion Engineering Test Reactor (CFETR) is due to be completed in 2030 and reported to be larger than ITER, according to the World Nuclear Association. Alongside tokamaks, there are research reactors that use different fusion technologies, such as stellarators and inertial confinement reactors.

ITER is a significant step forward not just because of its size, but because it will be the first fusion reactor that produces more energy than it consumes.

ITER's target is output of 500 megawatts from only 50 megawatts to start and maintain the fusion process. This is about the same amount of energy that a small fission plant produces.

"Fusion projects using tokamak technology are underway around the world, including in the U.S. and China"

Although this represents a tenfold energy return on investment, ITER will not capture the energy it produces as electricity. Instead, the project will fulfill its role as an experimental device, providing a wealth of technical information about many critical reactor components.

QST's Sugimoto points out: "The success of ITER does not immediately lead to a fusion power plant. The next step is to demonstrate power generation in the demonstration reactor, DEMO. Commercial fusion reactors should come online in the middle of this century."

Alongside government-led initiatives, there are also commercial initiatives, including two private laboratories in the UK, Tokamak Energy and First Light Fusion. According to the *Financial Times*, they are both aiming to complete their reactors by 2030 for commercialization.

Either way, there will still be some way to go before the "science fiction" of fusion becomes a reality, and can proactively help bring about a net zero world. ■

CHAPTER 2.

QUALITY OF LIFE

WHY AGTs ARE THE FUTURE OF SUSTAINABLE CITY TRANSPORT

By Johnny Wood / 2021-12-07

Driverless light rail systems have been moving passengers around the world's major airports for some time. But this same technology could provide a sustainable, cost-effective and versatile public transport solution for busy cities.

In airports, people movers transport high volumes of passengers over short distances at moderate speeds.

However, these Automated Guideway Transit (AGT) systems are also capable of covering more ground at higher speeds. This enables them to connect heavily populated suburban areas with busy urban centers. They can be built at a fraction of the cost of conventional light rail and with less disruption, but with similar benefits in terms of cutting emissions.

CLEAN AND EASY

Powered by electricity, the energy-efficient AGT system is a more environmentally friendly investment than expanding diesel-fueled bus networks and increasing the various exhaust emissions—including CO_2—associated with these.

Artificial intelligence (AI) and Internet of Things connectivity will boost the energy efficiency of AGTs further by recording passenger demand levels at different times of the day. This allows rail carriages to be quickly added or removed to meet changing demand—no energy is wasted hauling empty carriages during off-peak hours.

Rubber-wheeled AGT trains also produce less noise and vibration than conventional steel-wheeled railways, require less operating space, have lower operating and maintenance costs and shorter construction periods. This flexibility provides many benefits, such as the capacity to transport high passenger volumes and operate frequent services, without the hefty price tag.

FLEX APPEAL

Solutions that work in Tokyo, Hiroshima, Singapore and Macau can also help smaller cities in emerging economies.

Malaysia and many other Southeast Asian economies experienced rapid growth and a booming population throughout the 20th century, leaving little room for widescale town planning in many cities. Mass transport often had to fit in the remaining gaps or disrupt communities with major infrastructure projects.

In the bustling centers of historic towns like Penang and Malacca, AGT systems can be built on existing roads, helping preserve local identity by keeping land acquisition costs and disruption to a minimum, unlike Mass Rapid Transit (MRT) railway projects that need lots of land and often have to relocate entire communities.

> **"The rise in online working, with COVID-19 driving rapid changes in behavior, is expected to lead to a spike in cybercrime"**

"AGT's maneuverability means planners can follow narrow road reserves and reach into more densely populated areas housing working communities and mass transit commuters," said Khairul Khafizan, Senior Manager of Business Development at

MHI's Kuala Lumpur Liaison Office.

The ability to build-as-you-go means rail systems can start small, with low capital costs, allowing new sections to be added as city passenger flow increases.

"Systems are designed to carry between 2,000 and 30,000 passengers per hour per direction (pphpd), but can reach 50,000 pphpd, acting as feeder lines to urban centers and mainline rail stations for long-distance travel," Khafizan explains.

Cities across the region—from Kuala Lumpur to Hanoi, Jakarta to Bangkok—share many of the same transport challenges and growing pains.

Adopting AGT systems could be the solution. And with Mitsubishi Heavy Industries Asia-Pacific announcing the launch of its new Technical Service Center in Singapore, maintenance expertise and spare parts are always close at hand. The new center aims to strengthen operation, maintenance and after-sales services for its transport systems across Asia by introducing new services, such as failure prevention and diagnosis, as well as remote monitoring that incorporates digital and AI technologies.

The World Bank predicts that by 2050, nearly 70% of the global population will live in cities. With many of the world's most populated and fastest growing cities located in emerging economies, building driverless light-rail systems to connect cities with their suburbs could be the way to resolve urban transport challenges. ■

MHI'S CTO ITO ON TECHNOLOGY TRANSFORMATION AT MHI

By Eisaku Ito / 2021-06-04

When I was appointed as Chief Technology Officer of Mitsubishi Heavy Industries (MHI) Group in April 2020, I was given a clear mandate: to transform MHI's technological foundation in order to lay the basis for growth.

Very often, when companies talk about technological transformation, they really mean replacing jobs and cutting costs, or moving systems to the cloud. Such projects may make sense in themselves but are often not connected to wider business objectives or properly integrated across a company's operations.

What we are trying to do, however, is more fundamental and both broader and deeper. And while everyone I talked to, internally and externally, agreed on the need for urgent and radical action, most people told me that achieving this degree of change at a large Japanese multinational would be impossible.

I believe we are starting to prove the sceptics wrong. The first thing my team did was to audit what we already had—no small task in and of itself. We found that MHI's 30-35 Strategic Business Units (SBUs) produce more than 500 products based on 150 or so primary technologies. There are areas of great strength, for example in turbines and compressors; but also some gaps, for instance when it comes to electrification and artificial intelligence (AI).

We are filling most of these gaps by enhancing current products and expanding into adjacent fields. But we also wanted to take a fresh look at the horizon, so we launched "MHI Future Stream", an analysis of over 100 political, economic and social mega-trends using future-oriented foresight methods, to discover what brand new technologies MHI will require. This showed us the need to broaden our foundation to 200-250 technologies.

Many of these we will find externally via "technology scouting" at academic institutions and among start-ups around the world. We have put in place a new system for seed investments, allowing us to support entrepreneurs when they are still at the proof of concept stage and thus to build long, fruitful relationships. One such promising investment is into Infinium, a US company that uses captured carbon emissions to produce modern electrofuels.

The internal changes, however, are even more exciting—and profound, I believe. Traditionally, MHI has been big and slow: typically, a new R&D project was given 30 million JPY ($250,000) and one year to produce results. But we need to be quick and fast: I now give our engineers 3 million JPY ($25,000) and three months. I tell my engineers to be "faster than a start-up"—after all, they don't have to worry about raising money or renting an office.

I hoped to launch 100-200 projects in the first year with this new approach. We are already at 500: the explosion of ideas and creativity, especially from younger employees, has been wonderful to see. If the idea fails, at least it fails fast; if the result is promising, the team gets a fresh Y3m and another three months. Already, the first 400 projects have been completed and around 25% have produced prototypes or at least clear business hypotheses that are interesting enough for the strategic business units to incorporate them into their development plans.

We are just at the beginning, of course, but several core technology clusters are already emerging, including work around autonomous vehicles, electrification, heat management and new materials. We already build automated forklifts and self-guided

robot motions. The same technology can be applied to make unmanned vehicles for other applications on land and at sea, in the sky and in space. We are world leaders in capturing CO_2 emissions. Instead of storing the carbon underground, why not recycle it into products like car tires—people might pay a premium for a "green" tire.

Electrification, combined with our expertise in motors, turbochargers and mobile refrigeration units will allow us to create an end-to-end cold chain for sensitive commodities and products such as vaccines. Or take the naval ships of the future, which will fire not guns but lasers requiring power surges that traditional diesel engines cannot cope with. Our energy management systems with power generation, combined with our best-in-class heat management technology, can.

Of course, we need to set rules inside the company to make sure our research is always safe, ethical and has real-world applications. In fact, this is a global challenge, which is why I am happy to say that MHI was one of 600 companies that took part in the first Global Technology Governance Summit, held by the World Economic Forum in Tokyo, Japan, and virtually in April 2021.

We have a long way to go to achieve a fundamental technological transformation, but one year into the task I am increasingly confident of significant progress. ■

WHY THE WORLD NEEDS THE COLD CHAIN MORE THAN EVER BEFORE

By Johnny Wood / 2020-08-18

The business of keeping things cool is heating up fast. An ever-increasing need for tighter management of food safety and greater transparency, alongside growing concern about food waste, has seen cold-chain storage and delivery boom.

Temperature-controlled supply chains reach around the globe, transporting products including perishable food, beverages, and medical supplies to international markets.

With increased free trade and the expansion of the global organized retail food industry, the sector has flourished.

Market analysis predicts the global cold-chain industry will grow 17.9% a year by 2026, reaching more than $585 billion, with Asia-Pacific accounting for the bulk of this growth. Rising incomes in the emerging markets of Asia and other regions have increased cold-chain investments and opportunities as consumers seek higher-quality, fresh or organic produce.

In addition to this existing growth trend, the coronavirus pandemic increased demand for refrigerated trucks to transport perishable goods and created an urgent need to move vaccines around the world at controlled temperatures. This presented a challenge for cold-chain suppliers and operators aiming to make the sector as energy-efficient and environmentally friendly as possible.

STEPPING INTO THE UNKNOWN

The pandemic also, of course, created challenges. There was no blueprint for dealing with the impact on cold chains of lockdown restrictions, which threw panic buying, business closures and social distancing rules into the mix. Supply chains of all sizes had to respond quickly to sudden demand shocks: a step into the unknown for some operators.

Spikes in retail food and beverage sales, together with growing demand for goods like medical supplies and protective equipment, were met by falling demand from other parts of the economy.

With many food factory doors temporarily closed, the virus response disrupted both long-haul and local deliveries, as customer buying habits changed and fresh food orders from hotels, restaurants, and cafes largely dried up. This left wholesalers holding warehouses full of perishable goods.

In the face of these challenges, the cold chain was indispensable in maintaining a vital flow of refrigerated goods.

KEEPING IT COOL

Beyond these needs, refrigerated transport will continue to be critical in the development and distribution of vaccines.

Most vaccines need to be transported and stored at a constant temperature, from leaving the manufacturer to arrival at a medical facility or laboratory. Exposure to excess heat or freezing temperatures can result in lost potency, meaning the vaccine must be discarded.

The same controls apply to the raw materials used to produce vaccines. This is where the cold chain's role becomes vital. The latest transport refrigeration units, such as the award-winning plug-in hybrid system from Mitsubishi Heavy Industries Thermal Systems, are manufactured to keep the cargo hold temperature constant, even when the vehicle is parked or stationary with its engine idling. The system switches automatically between plug-in charging, alternator power and battery power, and between three power modes, to ensure the required temperature is maintained without relying on the driver.

More reliable refrigeration units can maintain consistently cool temperatures, with greater energy efficiency. As well as cutting CO_2 emissions, these units use up to 54% less energy compared to conventional refrigeration units, which will be important in the event that units are required to be in operation around the clock. They also reduce food waste, which in turn saves the energy used to produce wasted food and generates fewer emissions.

Most modern cold-chain equipment conforms to the United Nations' ATP agreement, which promotes safety and best practice in transporting perishable foodstuffs internationally by harmonizing the rules and regulations that apply to refrigerated transport.

"The need for efficient, transparent, and reliable cold-chain distribution and storage has never been more vital"

Although there is no unified global system for transporting medicines, cold-chain suppliers and operators must comply with good distribution practice guidelines to ensure the quality and integrity of medicines are maintained.

REACHING OUT

If mass distribution and storage of temperature-sensitive vaccines pose a challenge in developed economies, with solid energy infrastructure and consistent power supply to maintain storage temperature, there are additional challenges when dealing with poorer and less-developed parts of the world.

Remote communities in such places are not only harder to reach, they may have limited access to the energy infrastructure vital for preserving vaccine vials.

Technology can produce solar-powered cold-chain equipment and vaccine refrigerators that can overcome spikes in electricity, allowing some off-grid communities to store vaccines. But the cold-chain systems in some low- and middle-income countries are inadequate, and in some cases non-existent. Attempting to address this issue, international organizations such as Gavi are making efforts to strengthen vaccine cold-chain systems in many developing nations.

From remote communities to bustling cities, the need for efficient, transparent and reliable cold-chain distribution and storage has never been more vital.

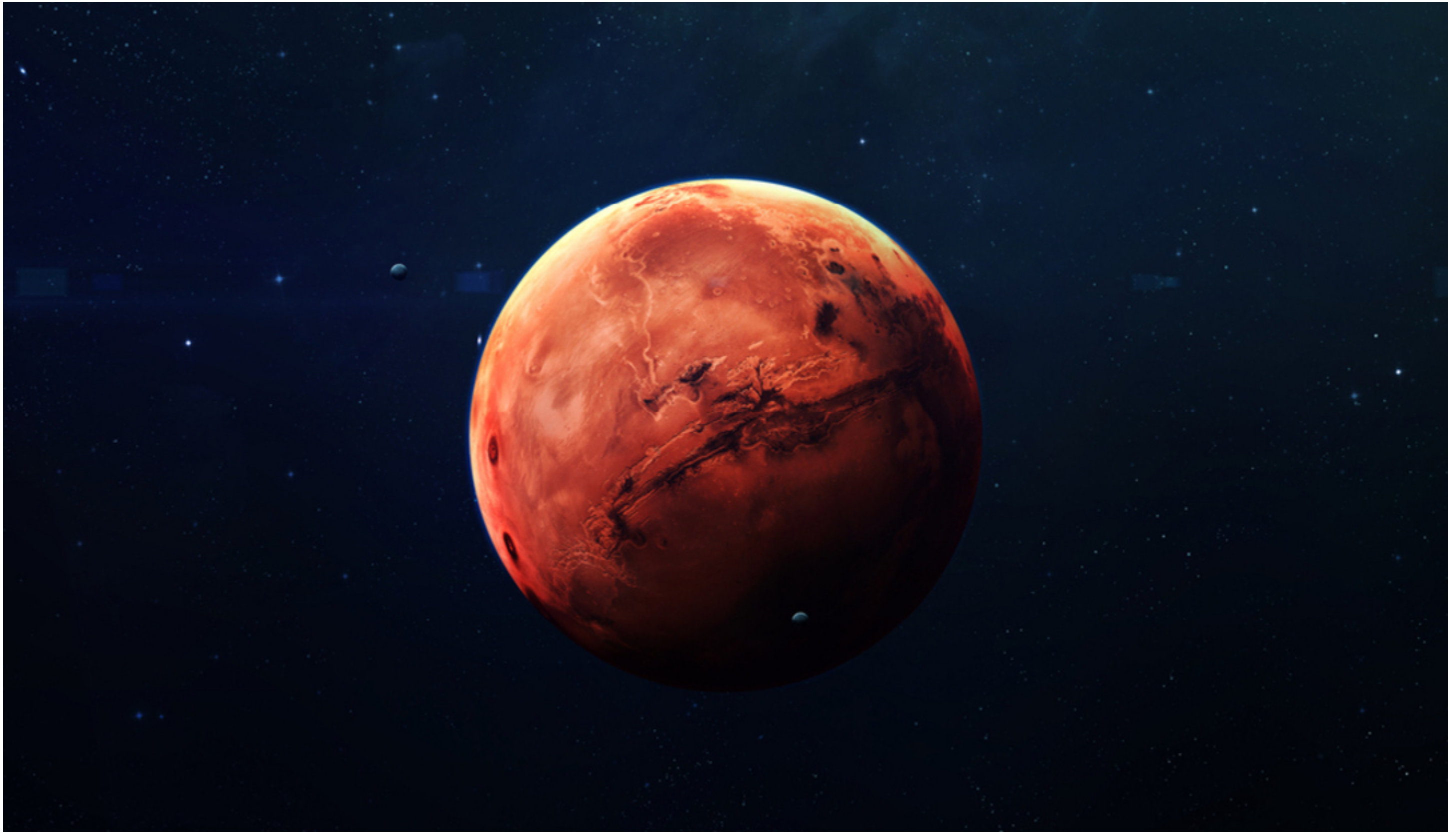
As well as keeping the supply of essential goods flowing, the sector is helping to improve food security and cut down waste, while also enabling medical supplies to reach their destination safely. ■

"In the face of these new challenges, the cold chain has been indispensable in maintaining a vital flow of refrigerated goods"

CHAPTER 3.

SECURITY & EXPLORATION

MARS, SPACE TOURISTS AND THE NEW H3 ROCKET



By Johnny Wood / 2021-06-10

On February 9, 2021, the United Arab Emirates' Hope probe slipped neatly into orbit around Mars, the successful culmination of a seven-month voyage from the Tanegashima space center in Japan.

Launched onboard Mitsubishi Heavy Industries (MHI) Group's H2A launch vehicle in July 2020, the UAE probe wasn't alone when it finally reached the red planet. Missions from China and NASA arrived in close proximity, a nod to the growing ambitions of today's space explorers set on venturing deeper into the unknown.

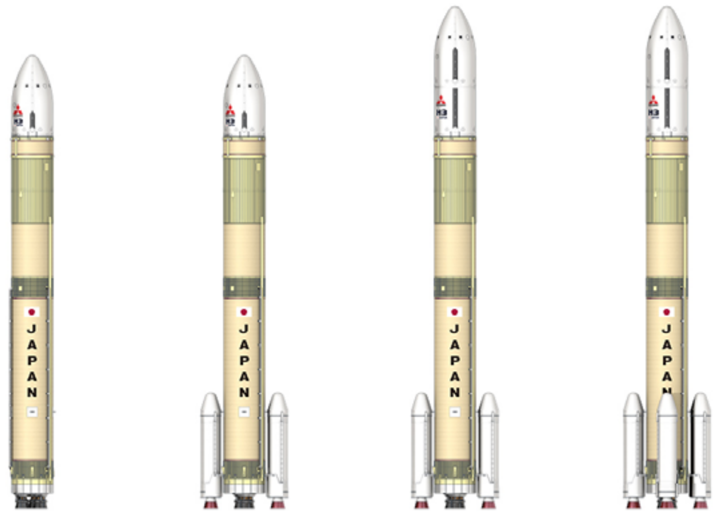
As the space sector becomes more ambitious and commercialized, it requires a new generation of launch vehicles that are capable of transporting bigger payloads as far as Earth's neighboring planets.

To that end, MHI's next generation H3 launch vehicle series has been designed to meet the changing needs of today's space industry.

NEXT-GENERATION SPACE TRAVEL

The H3 represents a new phase in MHI's space program, which spans more than four decades. Making launch services flexible and cost-effective is key as the private launch market becomes increasingly competitive.

"The H3 will help MHI better service both our government and our commercial launch partners," says Ko Ogasawara, who helped develop MHI's



launch vehicles and is now a professor at Tokyo University of Science.

So what are space businesses looking for when they choose a launch partner?

Today's launch market is characterized by a diverse range of satellites, comprising many different weights, shapes, sizes and functions.

Conventional communication satellites in geostationary orbit—positioned above the Earth's equator and following the planet's rotation—typically weighed around 4 to 6 tonnes. But a new generation of software-defined satellites is changing today's launch market, providing flexible communications satellites at around half the weight of conventional communication satellites.

In addition, the use of constellation programs at low earth orbit, where a batch of small satellites —each weighing a few hundred kilograms—are launched together to form a global network in space, is another trend transforming demand.

"We are seeing an increase in constellation programs with commercial and military applications for communications, Internet of Things or Earth observations, which presents exciting opportunities for launch providers," says Ogasawara.

The H3 range is bigger than that of its predecessors and has been designed with improved payload capacity, allowing greater flexibility. Utilizing spare capacity or initiating many small satellites from multiple launch partners on the same flight means individual launch costs are reduced.

The new launch vehicle looks set to conduct six annual launches initially, up from four or five currently, increasing to between eight and 10 over the coming decade. More launches allow the time between contract and launch to be reduced, giving H3's partners greater flexibility.

During manufacturing, costs are controlled by employing the spirit of Kaizen, or constant improvement, alongside advanced manufacturing techniques like 3D printing to produce components including engine parts, which are then assembled by automated robotic systems.

"I hope in 20 or 30 years from now, people can visit space hotels on platforms orbiting the Earth and enjoy weightlessness and a clear view of the stars"

Operationally, the H3 has an automated self-checking system that eliminates potential for human error, and ensures launches proceed on schedule, maintaining MHI's unequalled on-time success

"During manufacturing, costs are controlled by employing the spirit of Kaizen, or constant improvement, alongside advanced manufacturing techniques"

rate. A delay leaves the payload sitting on the launch pad instead of floating in space, which can have serious and costly business repercussions.

LAUNCHING HOPE

Developed in partnership with the Japan Aerospace Exploration Agency (JAXA), the new launch vehicle builds on the success of the H2 series, which sent the UAE's probe to the red planet.

Getting to Mars involved launching the Hope probe across millions of miles of open space. Traversing such a vast distance requires a high rocket mass to payload ratio, compared to the MHI launch vehicles used to launch supply missions to the International Space Station (ISS) or into low Earth orbit, both comparably close by in space terms.

In a first for the Arab world, the UAE orbiter will conduct scientific analysis of Mars' atmosphere and climate. Entering a high orbit, part of Hope's mission is to capture images of the planet's globe-like outline to study how energy moves through its atmosphere.

Future missions to Earth's far-flung neighbors can be better serviced with the H3's greater size and payload capacity.

In that future, Ogasawara talks of transforming then-decommissioned space stations like the ISS into low Earth orbit hotels for paying space tourists or building new space platforms as gravity-free factories among the stars.

"I hope in 20 or 30 years from now, people can visit space hotels on platforms orbiting the Earth and enjoy weightlessness and a clear view of the stars," says Ogasawara.

With the next-generation H3 launch vehicles designed for heavier payloads, and its experience of developing modules for the ISS with JAXA, could MHI one day add space tourism and stellar factory supplies to its list of launch services? Stranger things have happened. ■


CUP1_W4
CUP1_W3
CUP1_W1

DETECT, RESPOND, RECOVER: DEFENDING OUR MOST CRITICAL SYSTEMS FROM CYBERCRIME

By Harumi Mizokami / 2020-12-23

You are already infected! When it comes to cyber threats, that's what I as General Manager of Defense and Space Systems at the Advanced Systems Programs Department of Mitsubishi Heavy Industries (MHI) Group believe should be your mindset.

Every day, some 200,000 new pieces of malware are generated around the world. More than 60% of businesses experienced some type of cyberattack in 2018—from phishing or spyware to malware and ransomware. Two-thirds of these were individually tailored for a specific target. And since it takes over 200 days, on average, to detect a virus, we conservatively estimate that nine out of 10 companies currently carry viruses.

Nor is the danger confined to your laptop, phone and traditional IT systems. Nowadays, critical infrastructure, such as control systems for power stations, transportation systems or defense platforms, is just as vulnerable. It is such systems, commonly called operational technology systems, that we at MHI are seeking to protect and defend.

One reason OT systems are no longer safe is that while they used to be "offline", more and more of them are now networked. Rapid growth in the Internet of Things will only accelerate this trend. The supply chain can also be a weak point: if a component in a control system carries a virus then the whole system can be compromised. Often, such components are manufactured by smaller companies that do not have the resources or skills to guard effectively against cyberattacks. Governments and industry need to co-operate to overcome this challenge.

The biggest threat, however, is people. Some are malicious hackers, motivated by political or monetary gains. But most are just untrained employees, who do not practice good cyber hygiene. six years ago, as an experiment, US researchers left some anonymous USB sticks lying around a college campus in America. Almost half the students who picked one up plugged it into their computers without thinking twice. Now imagine if those USB sticks had been infected with spyware or malware?

So, if 100% protection against cyber threats is realistically impossible, the focus must be on three things: early detection; a rapid response; and then an efficient recovery of the (control) system. MHI's InteRSePT software does exactly that and is based on our long history and expertise in designing, operating—and fixing—critical infrastructure.

"The rise in online working, with COVID-19 having driven rapid changes in behavior, has led to a spike in cybercrime"

InteRSePT, which stands for "Integrated Resilient Security and Proactive Technology", constantly monitors the system on which it has been installed. That means it can detect anomalies defined in our profile algorithms, such as a drop in power triggered by a virus, in real time. It then immediately alerts the human operator of the system and recommends steps to mitigate the effect of the malicious commands and recover the system.

Also, InteRSePT supports a function that can prevent malware from executing a "kill" command.

To date, InteRSePT is in operation with a branch of the Japanese government and it is also being tested at several OT systems. We believe that demand for a product like this will continue to grow as global connectivity increases—one example is the move to remote monitoring of power stations, oil rigs and other critical infrastructure.

At the same time, the rise in online working, with COVID-19 having driven rapid changes in behavior, has led to a spike in cybercrime. We at MHI are ready to support our customers' efforts to fight against cyberattacks by making the best use of of our technologies and our knowledge of critical infrastructure. ■

CHAPTER 4.

MHI GROUP AT A GLANCE

FINANCIAL & COMPANY HIGHLIGHTS

$33.4 BN
Annual revenue
(FY2020)

25,968
Patents
(as of March, 2021)

47.4%
Sales outside Japan
(as of March, 2021)

$487 MIL
Profit from business
activities (FY2020)

78,880
Employees worldwide
(as of September, 2021)

257
Group Companies
(as of September, 2021)

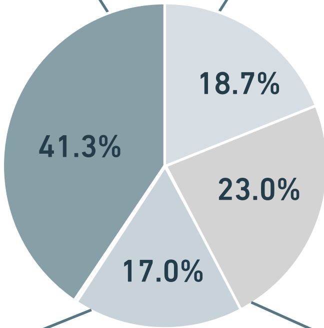
GROUP STRUCTURE

ENERGY SYSTEMS

- Clean gas and steam power systems
- Nuclear power systems
- Compressors
- Aero engineers
- Marine machinery

AIRCRAFT, DEFENSE & SPACE

- Commercial aircraft
- Defense aircraft
- Missile systems
- Naval ships
- Special vehicles
- Maritime systems
- Space systems



Composition of Revenue by Segment (FY 2020)

PLANTS & INFRASTRUCTURE SYSTEMS

- Commercial ships
- Engineering
- Environmental systems
- Metals machinery
- Machinery systems

LOGISTICS, THERMAL & DRIVE SYSTEMS

- Material handling systems
- Engines
- Turbochargers
- HVAC systems
- Automotive air conditioners

MISSION NET ZERO

Mitsubishi Heavy Industries Group will contribute to the realization of net zero for society as a whole

MITSUBISHI HEAVY INDUSTRIES