Moonshot R&D MILLENNIA* Program
*Multifaceted investigation challenge for new normal initiatives program

Toward establishing Japan as a New Ocean Nation by 2050
Create ocean infrastructure to drive the cycle of wealth accumulation, visualization, and optimal utilization of the oceans

Initiative Report

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Wealth of Ocean Nation

(WEON)

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I. Concept

1. Moonshot Goal

1.1 Proposed MS Goal

Toward establishing Japan as the New Ocean Nation by 2050:
Create ocean infrastructure to drive the cycle of wealth accumulation, visualization, and optimal utilization of the oceans

1.2 Vision for 2050 society

The ocean is the origin of all life. While we, human beings, still have little understanding of the ocean, the ocean is full of possibilities. Therefore, as an island nation with oceans, we propose a new economic system and life with oceans for Japan - the New Ocean Nation of 2050, which is sustainable and full of diversity. This proposal aims to draw a roadmap for addressing the world's issues that urgently need to be addressed.

The new Ocean Nation is guided by the ocean social infrastructure "Ocean Cycle," which is driven by economic motivations to wealth-accumulation, visualize and optimize the use of ocean-related data and other resources. First, ocean data obtained by space satellites, ocean robots, and other sensing technologies and data on the lives of ocean users are collected in real-time. By using a distributed ledger system based on blockchain technology, the data will be valued as commercial goods that can be traded on the market, and further data accumulation and ocean visualization will be promoted. As a result, the natural capital of the ocean, which brings the blessings of the ocean to society, will expand, and the "Satoumi Community 5.0" will develop, where it will be commercialized and used.

The Satoumi Community 5.0 is an advanced coastal community with flexible connections with other economic regions. While protecting the local ocean, the community is blessed by the local climate. The optimal use of the regional ocean shared by the community is accelerated. The growing ocean natural capitals will accrete benefits democratically in all aspects of life (food production and economic activities). The ocean and peoples' lives are deeply unified through Japan's unique ocean co-management. The community respects individual life, and people proactively choose the lifestyle that suits them from a broader range of spatial options. The Satoumi Community 5.0 is a new way of life and an ocean economy with the diversity of society and the sustainable use of the ocean.

Humanity will be back to the ocean, and by updating society from the ocean. By 2050, we will realize the New Ocean Nation will lead our world without poverty and hunger.

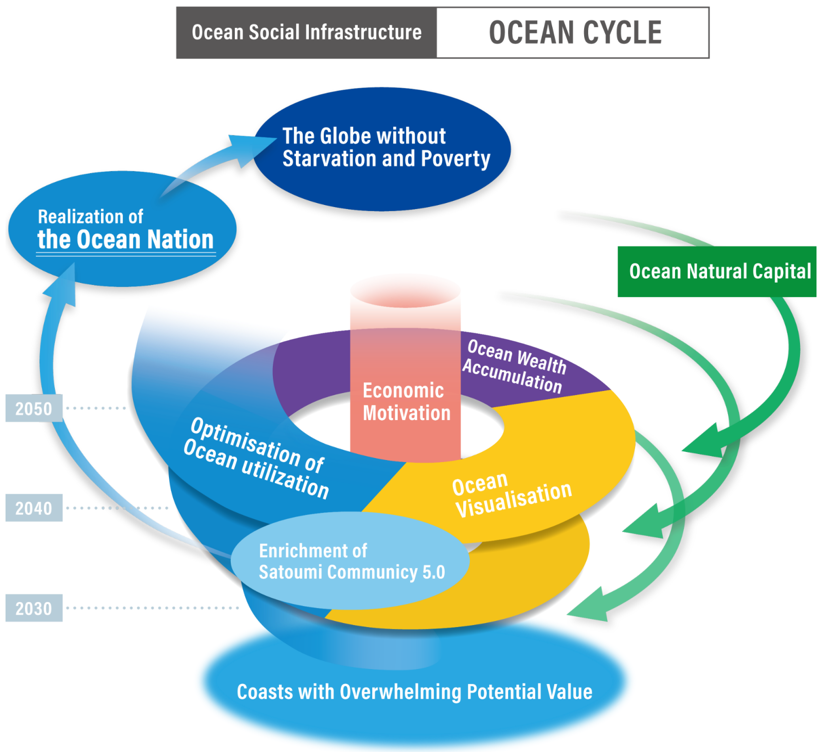


Figure I-1: Ocean Cycle proposed in the MS goal

2. Targets

By collecting a variety of oceanographic data, the following technologies will be implemented in society: monitoring and sensing technologies that promote ocean visualization, distributed ledger systems and data trading markets that contribute to the wealth accumulation and valorization of data, smart contract technologies that realize optimal use of data, and autonomous decentralized organizations. The following states will be realized.

Establishment of a new social infrastructure that maximizes the benefits of the sea while maintaining its ecosystem.

By the year 2050...

The "Ocean Cycle," social infrastructure of the oceans in which all data and other values related to the oceans are materialized, visualized, and used optimally, will permeate throughout Japan.

- Develop a social infrastructure platform to own, store, and trade all ocean-related data and the right of ocean use, and operate it throughout Japan.
- Establish a system for real-time monitoring, forecasting, and disseminating the status, supply, and demand of marine resources on beaches, at the sea surface, and under the sea throughout the coast of Japan.

- Develop a decentralized system for balancing supply and demand (demand and response) for sustainable resource use.

By 2030...

We will construct and experiment with an Ocean social infrastructure, "Ocean Cycle," in which the value of specific data and other information related to the ocean is materialized, visualized, and attempted to be used optimally.

- Develop a social infrastructure platform to own, store, and trade ocean-related data and the right of ocean use.
- Develop a system to monitor, forecast, and disseminate the status of specific marine resources on the beach, at the sea surface, and under the sea, as well as supply and demand, in real-time.
- Establish a data trading market for the exchange of specific ocean-related data.

A life that is friendly to the sea, rich in diversity, and rich in creativity, based on the Satoumi Community 5.0.

By the year 2050...

Many new economic activities that support proactive living will be created.

- The trade of ocean-related data and the right of ocean use will increase, and new economic activities will be created, including investment outside of the Satoumi Community 5.0 to which each member belongs.★1

市民目線コラム

★1. どこにいても、地元や海とつながって生きていける!

【技術】分散台帳システム、スマートコントラクト技術、自律分散組織

里海共同体 5.0 が、オーシャン・サイクルのもとで繁栄していくには、共同体の内部はもちろん、外部とのつながりも重要です。外の人々にも、共同体の各種権利に対する投資の門戸を開くことで、リターンとして共同体の施策決定への参加や、金銭、物品の配当など新しい経済活動が生まれます。例えば、洋上風力発電に投資することでどこでも安価なグリーン電力が賄えたり、海上観光開発に投資することで共同体を訪れた際に優待されたり。さまざまな理由で地元を離れた人も、場所に縛られずに主体的に地元経済を盛り上げ、海を守る一員になれます。

- The distribution of personal life-related data (food-related data, health data, etc.) as goods will diversify the sources of income. Linkage of ocean-related data and personal data will enable the provision of optimal food, medical care, and other services according to the health status of each individual.★ 2

市民目線コラム

★2. 自分が持っているデータを売ったら健康になれる!?

【技術】分散台帳システム

海洋のあらゆるデータが集まるデータ取引市場。そこで扱われるのは、漁獲量や推定資源量、気候予測データといった大きなデータばかりではありません。私たち個人が日ごろ買っている魚の種類や量、趣向、調理方法、日々変化するヘルスデータも貴重な商財となります。そうしたデータが研究機関や漁業者、水産関連企業で活用されることで、漁獲量や売値の設定、各自の健康状態の把握や将来予測など、様々な分野に大きく貢献します。自ら海に入って地元の海洋状態をセンシングし、データを集める活動が若者の中で流行ったり、各自の健康状態に応じた最適な食生活や医療情報が毎日届くようになったりするかもしれません。

Real-time and smooth reflection of will is possible.

- Through the device application, each person's will can be reflected in the Satoumi Community 5.0 and national management in an optimal way without any difficulty. ★ 3

市民目線コラム

★3. 社会のルールは選挙じゃなくてアプリで決める!

【技術】スマートコントラクト技術、自律分散組織

海洋を最適に利用するためにもっとも大切なのは、利用のためのルール作りです。沿岸地域の開発や、洋上発電機設置の賛否といった地域の意志決定は、各自のデバイスアプリを通して地域住民やステークホルダーの思いが掬い上げられ、完全に透明化されたプロセスの元で進められます。日々の暮らしと密接につながる共同体の細かなルールも、各自の意志をアプリに登録しておくことで最適解が導かれます。全ての人々が無理なく主体的に関わり生きる社会が実現します。

The ways to get close to the ocean will deepen and diversify.

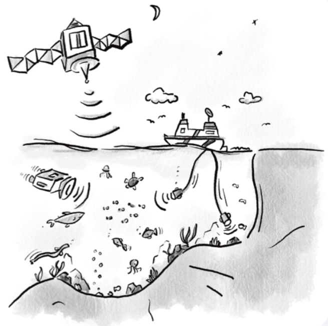
- Every area of the ocean will be monitored and sensed, and the map will extend to the inside of the ocean. ★4

市民目線コラム

★4. 海中地図を頼りに、どこにでも行ける!

【技術】分散台帳システム、モニタリング・センサリング技術

海洋を最適に利用するには、まず、海のことを知らなければなりません。分からないことが多い海洋を可視化するために、宇宙衛星を使った船の運航状況の観測や、無人運航船や海洋ロボットによる海上や海中のモニタリング・センシングが行われ、Google Sea Map のような海の中の正確な地図が完成します。人々が魚群ロボットと一緒に海中を泳ぎ回り、海の隅々までデータ採集に行く未来もそう遠くはないでしょう。



- A wide variety of fish, from popular species to rare varieties, can be enjoyed in season and at a fair price.★ 5

市民目線コラム

★5. 豊かな海の幸をいつまでも。

【技術】分散台帳システム、モニタリング・センサリング技術

海洋の可視化が進むと、海の中の資源量が分かるようになります。自然環境を守りながら資源を活用する、適切なペースがデータから導かれるので、持続的、安定的に魚を獲ることができるようになり、何百年先の子孫もまた、今と変わらずおいしい魚を食べることができます。日本の海域には多種多様な魚が生息しているので、生息数や生態が的確に分かれば、今まで価値が見出されていなかった希少な魚も適正な価格で市場に出回るようになり、私たちの食卓は彩り豊かな海の幸に溢れることでしょう。

3. Background

3.1 Why now?

a. Japan's destiny: The course is to the sea.

Surrounded by the sea on all sides, Japan is a long and narrow island nation stretching 3,500 km from north to south, and the interplay of warm and cold currents creates a highly variable climate. Combined with a complex and diverse coastal geography, Japan's oceans boast some of the world's most diverse ecosystems and overwhelming potential value.

Aspects of the world's oceans, encompassing transitions from subtropical to subarctic, are appearing in Japan's coasts and seas. Surrounded by continents and the Japanese archipelago, the Japan Sea, where cold and warm currents meet, is said to be affected by climate change before the rest of the world's oceans. In addition, since ancient times, our lives have been shaped by the culture of the coastal zone in order to adapt to its diverse climate.

Japan, with its unique geographic ocean conditions and diverse climate, must actively choose to live with the ocean and utilize it sustainably and to the fullest extent possible, so that it can exist as a solid Ocean Nation in 2050. This means showing not only Japan and its people, but also the world the way to create a society with the ocean as its starting point.

No matter how *Society 5.0* develops cyberspace, Japan in 2050 will certainly be with the physical ocean. Even if the social environment changes drastically and there are many disasters, the New Ocean Nation model will serve as a compass for the world and point the way to the sea.

b. Social demands: food, energy, and economic independence necessary in the post-Corona era.

In the course of overcoming the disasters of 2011, including the Great East Japan Earthquake and the pandemic caused by the coronavirus, we have come to understand that the sea is both a link and a barrier between Japan and the rest of the world. As an island nation, we must seriously address the issue of Japan's independence in terms of food, energy, economy, and national security.

The recent history of the oceans, once called an inexhaustible treasure chest, has been a painful one: the richness of the natural coastline and fisheries have dwindled, the public has lost interest in the oceans and coastal areas, and fisheries are in decline. A ray of light lies in the steady accumulation of best practices that show that even if marine living resources are diminished, they can be recovered through proper resource management, and in the development of science and technology that enables the search for robust management methods through large-scale computer simulations. In addition, there are high expectations for the ocean potential, including offshore wind power, in decarbonization efforts to meet the urgent need for increased energy demand.

When the greatest common denominator of society's needs for the year 2050 is sufficient food to support individual health and a healthy economy, Japan must now be prepared to meet these needs with its marine resources and find a way to become self-reliant.

c. Scientific and technological imperatives: An environment to overcome the challenges of the ocean.

Science has shown that sustainable and stable production and consumption of marine resources can significantly improve the global food supply to feed the growing world population (Costello et al. 2019). Building on this and other scientific papers, in 2020, the High Level Panel for a Sustainable Ocean Economy, composed of 14 of the world's major Ocean Nations, including Japan, has declared that it will build a sustainable ocean economy that provides innovative solutions to global challenges.

d. Need for long-term initiatives: Impact on national governance, including legal and institutional reforms.

The New Ocean Nation of Japan will be guided by the "Ocean Cycle," an economically motivated system of Ocean social infrastructure in which ocean-related data and other information are materialized, visualized and used optimally. However, the social implementation of this infrastructure requires not only domestic legal and institutional reforms, but also standardization of data and other information with an eye to global trends. In order to be accepted by Japanese society, even a single technology or system for commercializing ocean-related data and rights will need to be coordinated with existing social norms and business practices and will have a driving force for change in politics and national governance.

e. National level value: He who controls the ocean cyberspace controls the world.

Along with space, the oceans are another area that has yet to be explored, and cyberspace is a completely unexplored area. If we lead the oceans in both physical and cyber space, we will become the world's flag bearer and contribute greatly to the development of the entire world.

In recent years, there has been a rapid increase in information and knowledge about the ocean itself and its economic, social, and environmental values. In the background, there is a movement in Europe and the United States to evaluate the value of the ocean economically and to create an environment for investment, which needs to be closely monitored (Sumaila et al. 2021).

3.2 Social significance

a. The ocean has enough potential to change the world.

Not only in Japan, but also in other countries, ideas, and technologies related to the future ocean, such as offshore cities and marine farms, have very high hurdles for social implementation, and no country has yet been able to draw out the potential of the ocean and use it to its full potential.

However, it is Japan's destiny to create the New Ocean Nation model and to demonstrate the potential of the ocean to the world, which can only be achieved by Japan being surrounded by the ocean, which boasts one of the world's most diverse ecosystems and overwhelming potential value. Our Moonshot Goal is of immeasurable value, as it will extend and renew the industries, science, and technology that have developed on land to the sea.

Japan's ability to use the oceans within its jurisdiction sustainably and to the fullest extent possible will mean that it will be a contributing nation at the global level, offering the possibility of sustainable development to all other nations involved with the oceans, including landlocked nations.

b. The influence of science and technology-based infrastructure is far-reaching and leads to social change.

Our Moonshot Goal emphasizes the importance of realizing the "Ocean Cycle". It is the economic and social infrastructure that will become the driving force behind Japan's growth into a nation with new values originating from the oceans, as both fishery workers and citizens with little interest in the oceans follow economic incentives to make the best decisions possible. The social significance of the implementation of this project is enormous, as it will have a ripple effect that will promote a wide range of social changes, including the development of science and technology that will promote the use of the ocean, the emergence of new ocean businesses, and the diverse and creative lifestyles that these businesses will lead.

c. Ensure both the diversity and richness of society and the sustainable use of the ocean.

In a society guided by the "Ocean Cycle," people will be able to independently choose how to live from a variety of options, and at the same time, ocean natural capital will be protected from the "tragedy of the commons," in which many selfish actions lead to the depletion of ocean resources and the loss of benefits. The optimal use of the oceans for individuals and society can be achieved. Smart contracts and autonomous decentralized technologies will democratically choose options for sustainable ocean resource use, and these choices will gradually be reinforced and become routine. A truly sustainable society that does not sacrifice people's wealth will be realized.

3.3 Action outline

In the "Ocean Cycle" that forms the basis of our proposed Moonshot Goal, the ocean and its utilization data are a fundamental element for all areas, so we will use data as a starting point to outline the efforts of society as a whole.

a. Data collection

In addition to the government, which has a wide variety of data, major marine industry players such as shipping, shipbuilding, fisheries, and fisheries-related industries, and marine recreational industries need to actively cooperate in collecting, publishing, and providing biological, physical, and economic and social activity data. The public is also expected to cooperate in the collection of data on the ocean and its use around them. Institutional design and improvement of social acceptability, including literacy, are required to make this possible.

Efficient data collection involves the following industries: electronic devices, electronic components, industrial electrical equipment, consumer electrical equipment, electronic application equipment and electrical measuring instruments, electrical machinery, telecommunications, video and audio equipment, and electronic computing.

It is necessary to design a system that enables the collection, disclosure, and provision of appropriate data on the ocean and its use, and to improve social literacy.

b. Use of data

It is expected that a wide range of information-related industries, such as information services, software, application service content providers, AI-related industries, publishing, and advertising, will create new values based on the widely collected ocean and its usage of the data. One of the outcomes of our Moonshot Goal is that a wide range of industries, including finance, insurance, and real estate, which are involved in the market for goods, including data and information, will be added to the existing ocean industry. This will require technological development and institutional design related to the trade and use of data and goods in each sector.

4. Benefits for industry and society

a. Changes in industrial structure

At present, the ocean-related industries consist mainly of shipping, fishing, and related industry groups. By overcoming the uncertainty of the ocean, Japan can expand the ocean natural capital and build a system to use the ocean sustainably and to the maximum extent possible. This will become a foundation that supports society as a whole.

The driving force behind the "Ocean Cycle" consisting of "wealth accumulation," "visualization," and "optimized utilization," which will be discussed in detail in the next chapter, is designed to be "economically motivated. This means that as a result of the successful rotation of the cycle, capital will be invested in related ocean industries, and new ocean industries will be established. As a result, society's relationship with the ocean will change drastically, and it will also have a transformative effect on areas far removed from the ocean.

At the bottom of this Ocean Cycle, ocean-derived goods (data, information, usage rights, and value) flow together with ocean resources. In particular, by treating ocean data as goods, AI-related industries will develop significantly based on ocean natural capital to solve the question, "How can we safely and promptly collect, trade, process, use, and reproduce ocean goods? In particular, by treating ocean data as goods, it is expected that AI-related industries will develop greatly based on ocean natural capital to solve the question, "How can we safely and promptly collect, trade, process, use, and reproduce ocean goods? Furthermore, the resulting visualization of the ocean will enable the fisheries, marine energy, and shipping industries, which have traditionally used ocean resources, to develop their industries more efficiently. In particular, the fishery industry, which relies heavily on intuition and experience, will be able to operate efficiently without relying on intuition and experience if ocean visualization and optimized utilization are achieved, and the barriers to entry into the industry will become infinitely smaller, resulting in a diverse population.

b. Changes in social structure

As mentioned above, the primary industry of fishing (and various other primary industries by applying this cycle to other primary industries) will become an attractive occupation for everyone. This will solve the shortage of workers, and the production of food from the ocean will save the world from starvation. Furthermore, as decision-making based on the uncertainty of the oceans and nature becomes the norm, the entire population will be involved in determining how to use common goods and the policies to do so, based on the assumption of future uncertainty. In addition, as society as a whole is supported by marine-derived industries, interests, economies, and lifestyles will be dispersed to seaside locations throughout the country. By designing employment systems based on dispersion, more and more people will have dual jobs in marine-related fields.

The renewed marine industry will become Japan's core industry, primary industry will be reborn in a new form based on nature, and the social structure will change drastically as more and more people become involved with the ocean.

II. Analysis

1. Essential scientific/social components

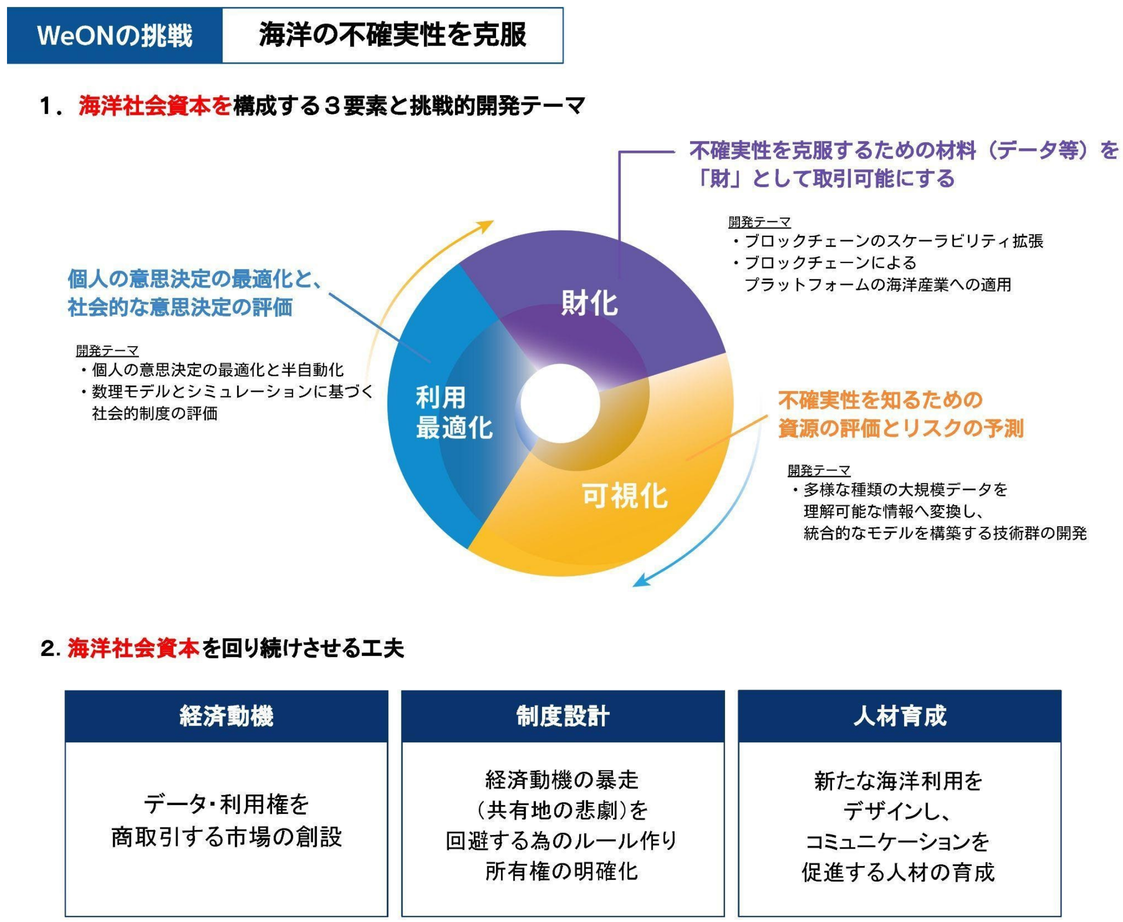


Figure II (1) The three elements that make up the ocean social capital "Ocean Cycle" and challenging development themes; (2) How to keep the Ocean Cycle going

a. Uncertainties of Ocean

To achieve the Moonshot Goal of the New Ocean Nation, Japan, the most significant challenge will be overcoming the uncertainty of the oceans. Although the importance of the ocean economy has been recognized and the need for investment in ocean-related projects has been called for, the actual amount of investment is low. For example, impact investment in Sustainable Development Goal (SDG) 14, "Life below water," is the lowest of the 17 SDGs (Libes and Eldridge 2019). Despite the recognition of the ocean's potential for development through impact investment and other forms of funding, the lack of funding is not only due to a lack of attractiveness to encourage investment, but is also largely due to a lack of information and data on the ocean itself and its economic, social and environmental value (Sumaila et al. 2021). In general, investment in projects involves a trade-off between risk and return. Some investment projects have low returns with low risk, and others take high risks for high returns. In the case of social or national projects, social impact would be concerned in addition to financial return, but the risk evaluation is still required even in this case. In order to promote investment in the oceans, and thus the optimal use of the oceans, it is necessary to overcome two uncertainties: the lack of understanding due to the lack of information about the oceans (uncertainty due to lack of knowledge), and the fact that much of the ocean system itself is subject to stochastic processes (stochastic uncertainty).

While it is impossible to completely eliminate uncertainty, it is possible to reduce uncertainty due to lack of knowledge by accumulating scientific knowledge. Furthermore, although we cannot completely eliminate probabilistic uncertainty, we can quantify the magnitude of uncertainty as risk by viewing the subject as a probabilistic process. In other words, instead of trying to predict the outcome of a roll of the dice, we need to observe the dice closely and develop techniques to accurately capture how many rolls there are and what the probability of each roll is. With these two approaches, we will overcome the uncertainty of the ocean.

Information is essential for scientific knowledge, and a vast amount of data is necessary to obtain information. The lack of scientific knowledge on the ocean compared to that on land is due to the difficulty of observation, or invisibility. The ocean is a huge three-dimensional space with a vast sea surface and depths, and it is difficult to observe because light cannot reach a large area and human access is limited due to the fact that it is underwater. Even once an observation has been made, the sea is constantly changing due to the influence of tides, seasons, and currents, and fish are constantly on the move. In addition to sudden threats such as storms, surges, and tsunamis, climate change is slowly but surely changing the ocean. Synchronously and diachronically, the ocean is invisible.

b. The Challenge of Collecting Data to Reduce Uncertainty

Reducing uncertainty in the oceans is highly dependent on the amount of data available, and thus requires technologies and mechanisms to collect a wide range of data about the oceans. Conventional ocean data collection has mainly involved the collection of survey data for research purposes. While such collection methods are important, as the use of the oceans expands, the collection of data associated with that use will become key. The recent big data boom is due to the widespread use of sensor technology, cameras, microphones, and mobile devices, as well as the expansion of information technology (IT), which has led to the creation and recording of data through the use of services, rather than for the purpose of collecting data itself. In the same way, ocean data will be ready for optimal use only when an information infrastructure is in place that can continuously collect and accumulate large amounts of data based on ocean use. Such an information infrastructure provides a mechanism for obtaining data (records) about the ocean (data collection), storing the obtained data (data accumulation), and processing and analyzing the data (data analysis) to create information with value that triggers economic incentives (data informatization).

Perhaps the most significant barrier to data collection is the cost of collection. For research purposes, such as those mentioned above, there are extensive oceanographic observation networks consisting of satellites and unmanned sensors floating in the ocean, many of which are scientifically motivated and funded by large amounts of public fundings. But what about the data generated by human activities in the ocean and the process of exploiting ocean-derived resources? For example, before a single saury is caught and consumed, a variety of data is generated, including the location of the catch, the fishermen who caught it, the sea conditions at the time of the catch, the trade price, distribution channels, and consumption patterns. The reason for this is that it is costly to record a wide variety of data at the right time. In order to collect and utilize such data, the key to increasing the amount of data is to reduce the labor, cost, and time required for data collection, and to create a mechanism for continuous data collection.

Another reason why ocean usage data is not being collected in a comprehensive manner is that it is directly related to personal privacy. For example, fishers have data on how many and what kind of fish they catch and at what price in what waters, but even if this data is essential for visualizing the ocean, they will not readily provide it to others if there is even the slightest risk of it being passed on to competitors.

c. Social Mechanism to Overcome Challenges in Data Collection: The Ocean Cycle

In order to build a new Ocean Nation, Japan, it is necessary to collect data related to the use of the ocean and to reduce the uncertainty. This requires a new social infrastructure and a transformation of the socioeconomic system to promote ocean use based on economic motivation. New data will be accumulated by collecting data, analyzing the data to understand and visualize the ocean, and using the information to expand the use of the ocean. By circulating such a cycle of visualization and utilization, Japan's ocean utilization can be optimized while ensuring sustainability and expansion. If a spiral of development is established through this cycle, Japan will grow into a nation that makes maximum use of the ocean in a sustainable manner.

What is needed to complete the cycle of visualization and use optimization is a mechanism to overcome the challenges of data collection, such as cost and confidentiality, and to provide economic incentives to users of the ocean. As a mechanism to overcome these challenges, we propose the construction of the "Ocean Cycle" by incorporating the "wealth accumulation" of the ocean into the cycle. Wealth accumulation is the process of making data and ocean usage rights into objects of value that can be owned, stored, and traded exclusively. The Ocean Cycle will be a game-changer for Japan in ocean utilization and will serve as the backbone of Japan to establish the new Ocean Nation.

(1) OCEAN WEALTH ACCUMULATION

Making ocean data and the right of ocean use tradable through ocean property will increase the amount of data that contributes to the visualization of the ocean and encourage more active use of the ocean. Wealth Accumulation is the starting point of the Ocean Cycle and the economic incentive to keep the cycle going.

The development of social infrastructures that allow for the exclusive ownership, storage, and trading of data and rights is essential to the promotion of “Wealth Accumulation”. This includes technologies that prevent data from being easily duplicated or used without the knowledge of the provider, as well as mechanisms to protect the rights of data owners. **Blockchain technology, a form of distributed ledger technology, is a complex elemental technology that has the potential to meet all of these demands at once.**

The biggest challenge for science and technology in promoting Wealth Accumulation by blockchain technology is to solve the trilemma of scalability, security, and decentralization. If this challenge can be overcome, it will be possible for many individuals to automatically trade goods on a national scale, quickly, securely, and under certain conditions. In order for these technologies to become widespread by 2050, it will be necessary to build a social infrastructure so that data on every fish caught in the nation can be traded by 2030.

The social issue is the current laws, regulations and systems that prevent the creation of a commercial market for goods. This is exemplified by the development of laws such as the Personal Information Protection Law and the Financial Instruments and Exchange Law regarding the ownership and use rights of digital data and the transfer of rights, as well as the design of systems for the automated trading of these rights. Amendment of the Fisheries Law is required for the rights and transfer of marine use.

If we can create a socioeconomic system in which data has value as a good, we can expect that the sophistication of observation technology and the collection of data on oceanographic observations and human socioeconomic activities using newly developed sensors will naturally become more active at all levels of citizens, scientists, businesses, and governments in various sectors.

(2) OCEAN VISUALIZATION

Even if the wealth accumulation of the oceans facilitates data collection based on economic motives, it does not mean that the entire ocean will be understood. What is required in the era of Big Data is not just the accumulation of data, but also how to generate meaningful information from the data. The next step in the Ocean Cycle is to visualize the oceans, that is, to elucidate the processes of the oceans and their relationship to human activities, and to build a mechanism to extract the necessary information for optimal utilization.

The scientific and technological challenge will be to develop the methods of investigation, analysis, and modeling in existing research approaches to keep pace with the increasing availability of data. One of the first implications of increased data availability is that it will enable the application of complex modeling and methods that were not previously possible. This refers to the application of currently developing methods such as causal inference and artificial intelligence to advance the modeling approach to understanding nature. The potential challenges here include not only the technology itself, but also the lack of human capacity. Secondly, the combination of different types of data opens up new research possibilities. For example, combining data from satellites and sensor rings with data used in the field to complement the information obtained from each.

(3) OPTIMIZING THE USE OF OCEAN

Even if the wealth accumulation and visualization of the oceans is realized, a framework is needed to value and use the oceans and their natural capital at the optimal time and in an optimal way. Historically, marine resources have been positioned as non-excludable and competitive public goods (common resource goods), and as a result, they have been subject to competition and deprivation, and the benefits derived from marine resources have been lost (the tragedy of the commons). A new ocean use system needs to be proposed to protect marine natural capital from the tragedy of the commons and to use it in a way that is optimal for society and for individuals. The theoretical framework is based on social choice theory and provides a framework for examining the effectiveness of institutions and policies through simulations of natural and social systems, using marine resource management as an example, where numerous social implementation experiments have been accumulated.

The science and technology that needs to be developed for use optimization is a simulation system for proposing a new ocean use system to avoid the tragedy of common land and optimize its use. Every policy and institutional choice has its advantages and disadvantages, and they vary depending on one's position in society. By conducting simulations to quantitatively and scientifically understand the consequences of policy and institutional choices, and by sharing this information, we can promote consensus-building based on more constructive discussions. This simulation has begun to be applied mainly to fishery resource management by integrating models from natural and social sciences. It is expected that the data and information collected through the process of wealth accumulation and visualization of the Ocean Cycle will make this technology even more applicable to the real world.

It is a social issue to decide who should be responsible for the use of marine natural capital in use optimization. Treating rights, such as ownership and use rights, as tradable goods in the market and attempting to achieve the most efficient allocation and use is known as rights-based management, which is spreading around the world and has achieved a certain degree of success. On the other hand, it is also true that the method of granting rights to individuals and corporations individually has encountered problems such as inducing speculation that deviates from fairness and the original purpose. Against this background, an approach in which local communities and other groups rooted in the region are the rights holders is beginning to attract attention. For example, in the case of Japan's fisheries industry, communities such as fishing cooperatives have mainly managed and used their own resources, but social science research is also essential, along with scientific and technological development, to create a framework in which such groups can become the new right holders of the right of ocean use and promote management and use.

d. Challenges in Driving the Ocean Cycle

(1) ECONOMIC MOTIVE

As has been mentioned many times before, economic incentives are the fundamental drivers behind the functioning of the Ocean Cycle, the social infrastructure of the ocean. The ocean users who collect and provide the data need to be compensated in return for distributing the data. The major challenge has been that data collection is a costly activity for ocean users, yet the benefits do not exceed the cost. Providing this benefit through technologies that allow for the exclusive ownership, distribution, and trade of data is the overriding goal of making the Ocean Cycle work.

(2) INSTITUTIONAL DESIGN

Although economic incentives are the most fundamental driving force for collecting and using data to overcome uncertainty in the oceans, incentives alone can lead to failure of ocean use as the tragedy of the commons illustrates. The handle that controls this power is an institution that aligns individual incentives with the overall optimal objective. The two major issues here are the design of data management and markets for the wealth accumulation of data, and the design of institutions for the optimal use of marine natural capital. The blockchain technology is applied to contribute to the former objective. In addition, it is necessary to design a system that prevents the use of data in ways that may deviate from its original purpose. As for the system of usage rights, it is not a simple system design, but a well-balanced system design that is consistent with the culture and norms that exist in the region, while at the same time making the rights clearer than before.

(3) HUMAN RESOURCE DEVELOPMENT

In order to drive the Ocean Cycle, it is essential to develop human resources who can design new ocean uses, communicate with various stakeholders, and coordinate interests. The lack of such human resources has been pointed out as an issue in the use of marine resources for many years, but the reason why the issue has not been resolved is that there is no fundamental human resource development system. In terms of the design of ocean utilization, there is a lack of human resources in Japan who understand the ocean as a resource and research and disseminate information on its utilization in terms of natural sciences, social sciences and humanities. In order to solve these problems, it is necessary to establish a system for human resource development and education.

2. Japan’s position in overseas trends

In order to overcome uncertainty in the oceans through science and technology, three major types of research and development are required.

The first is the wealth accumulation of the ocean. The wealth accumulation of the oceans is an indispensable element that is the starting point of the Ocean Cycle. This project focuses on blockchain technology to develop a social infrastructure to realize the wealth accumulation of the ocean. By solving the bottleneck of blockchain technology, we will create an economy in which goods are decentralized and managed and traded on a nationwide scale.

The second is the visualization of the ocean. Visualizing the ocean is not only a way to understand and reduce uncertainty, but also an incentive to collect ocean data. By collecting, integrating, and analyzing vast amounts of ocean data and ocean usage data, we can not only visualize the "current" ocean situation, but also promote the visualization of the "future" ocean through forecasting.

The third is the optimization of ocean use. The technology of use optimization completes the cycle of improving the efficiency of ocean use based on the results of wealth accumulation and visualization. However, decision making in the presence of multiple stakeholders with different values is not an easy problem. This project will address not only the optimization of individual decision-making, but also the problem of social decision-making and the evaluation of social institutions.

Research and development to overcome these uncertainties in the ocean will aim to achieve both economic development and social issues by developing "Satoumi Community 5.0" in various regions, which will sustainably maximize the use of local oceans rooted in the climate by highly integrating the physical space of the ocean and the cyber space managed by blockchain. Our Moonshot Goal is clearly in line with the concept of "Society 5.0", which was a pillar of the 5th Science and Technology Basic Plan, and the intention of the 6th Science, Technology and Innovation Basic Plan, which calls for the social implementation of "Society 5.0" (6th Science, Technology and Innovation Basic Plan).

Figure II-2-1 shows the issues to be overcome by arranging the research and development fields to be tackled to achieve this Moonshot Goal using the axes of the ocean visualization level and the ocean optimized utilization level, and noting the results to be obtained in chronological order.

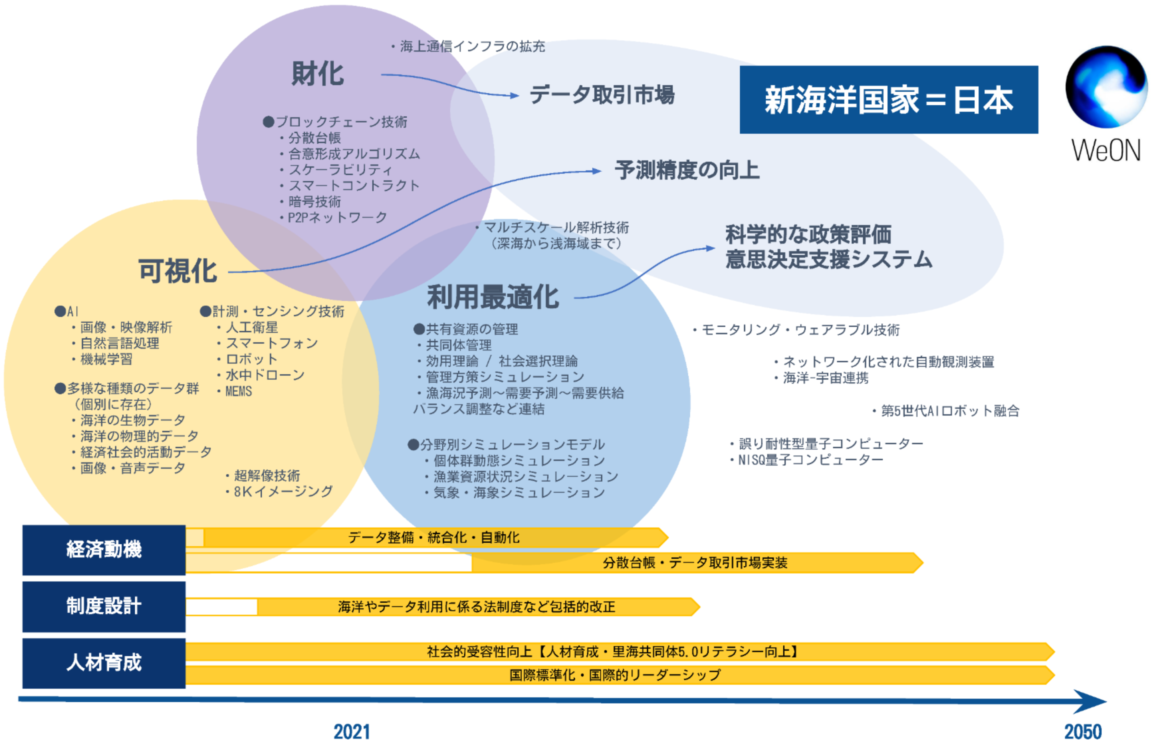


Figure II-2-1: ***Issues to be overcome by science and technology and R&D fields necessary to overcome the issues***

a. To promote the wealth accumulation of the oceans

In order to promote the wealth accumulation of the oceans, it is essential to develop a social infrastructure platform that can own, store, and trade data and rights. Blockchain technology, a form of distributed ledger technology, is a complex elemental technology that has the potential to meet all of these demands at once.

This section first provides an overview of blockchain technology, organized by hierarchy, and gives a general direction for the types of blockchain that match the requirements of the Moonshot Goals. Next, we will summarize the challenges that must be overcome through science and technology in order to promote the wealth accumulation of the oceans. Next, we will summarize the bottlenecks in terms of social implementation of a social infrastructure platform based on blockchain technology, and discuss the current prospects for breakthrough technologies. Finally, the transition of blockchain technology development and the structure of related fields and technology groups will be reviewed.

OVERVIEW OF BLOCKCHAIN TECHNOLOGY

In a narrow sense, the term "blockchain" refers to a form of distributed ledger in which chunks of data called "blocks" are linked together on a network. On the other hand, in a broader sense, it is used to refer to "a P2P network technology system that serves as the foundation for distributed applications," so this report will refer to it in a broader sense as "blockchain" or "blockchain technology. Blockchain technology has attractive features and functions such as distributed ledger, unfalsifiability, traceability, distributed consensus building, and transaction functions. In particular, a feature called smart contracts, which refers to the automation of contracts, enables the management and processing of information other than value exchange by incorporating certain programs in the transaction information. Demonstration experiments and platforms based on this mechanism are being conducted around the world (JST 2019).

Figure II-2-1 (Layer 1.0-4.0 hierarchy using the Ethereum platform as an example) shows a hierarchical organization of the protocol technologies that define the blockchain. As shown in this figure, blockchain-specific technologies such as distributed ledger and distributed consensus building (Layer 1) are located on top of general-purpose technologies such as cryptography and P2P network technologies (Layer 0). Higher layers include a layer for smart contracts (Layer 1.5), a layer for scaling (Layer 2.0 and Layer 2.5), and a layer for general-purpose application technology (Layer 3.0).

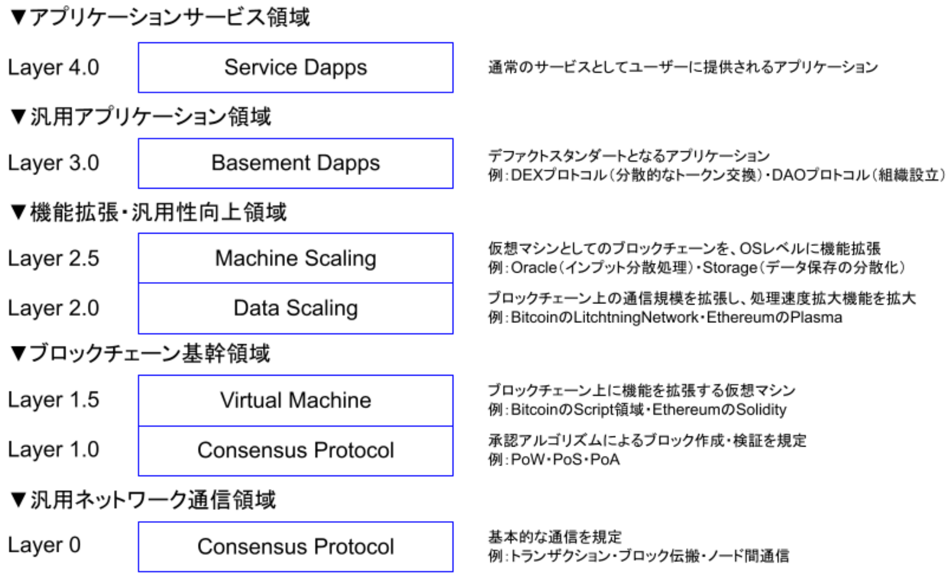


Figure II-2-1. Layered structure for understanding the protocol domain of blockchain (modified from GincoMagazine editorial 2018).

Platforms based on blockchain technology can be roughly divided into two types: public and private. The public type requires strict approval for block creation and source code modification, as there is no administrator and anyone can participate. In addition, changes to the blockchain specifications require the approval of an unspecified number of people, and frequent changes are not easy. On the other hand, a large number of nodes are operating in a distributed manner, resulting in high security performance. The private type, which has an administrator and requires permission to participate, has the opposite characteristics to the public type. When a private type blockchain is shared among companies or a limited number of individuals, it is called a consortium type. In the consortium type, a specific approval algorithm has been proposed, which takes advantage of the assumption that the network consists of trusted nodes.

In the Moonshot Goals, first of all, the realization of transactions at a speed that does not interfere with operations under high security performance is required. Secondly, a flexible blockchain is required that can handle frequent updates as the platform grows and trading rules change. Based on these two preconditions, I will give an overview of the types of blockchains that are candidates for this goal, and describe the challenges they need to overcome.

Public blockchains are not suitable for this Moonshot Goal.

Although the public type is supported by a strict approval algorithm and maintains an unspecified number of nodes, it is not suitable for application to the Moonshot Goals for the following two reasons. The first reason is that, as mentioned above, it is difficult to deal with frequent updates. For example, in the case of the public Ethereum platform, it is known that it takes multiple years to make large-scale changes to the approval algorithm due to non-technical factors (Young 2021). The second reason is that the platform is supported by the behavior of non-stakeholder participants. The second reason is that the platform is supported by the behavior of non-stakeholder participants, and the problems this causes are somewhat complex.

Public chains require all processing fees paid with potentially speculative cryptocurrencies, leading to volatile and unstable operating costs in transaction systems. For this reason, public chains often experience delays in completing transactions, as the transactions with the highest value are processed first. This delay is exacerbated by the fact that the entire chain can only process a limited amount of transactions in a given amount of time, so there will be many other accounts submitting more transactions. Therefore, public chains are not suitable for the platform envisaged by the MS goal, which is based on processing a lot of data.

CHALLENGES TO BE OVERCOME BY SCIENCE & TECHNOLOGY

The trilemma of scalability, security, and decentralization

There is a concept called the "blockchain trilemma" presented by Vitalik Buterin, the inventor of Ethereum. This is a restriction that only two of the three elements of scalability, security, and decentralization can be met simultaneously. Scalability is the degree to which processing power can be increased. Security is the degree of difficulty in successfully attacking the blockchain. De-centralization refers to the degree to which anyone is free to create "nodes" to verify blocks (permissionless), the degree to which the blockchain can function without trusting other nodes (trustless), the degree to which the blockchain is not dependent on any particular node (no single point of failure), and the degree to which the blockchain is actually operated by a large number of distributed nodes. (Hoshi 2018).

Typical public platforms such as Bitcoin and Ethereum achieve high security and decentralization, but at the expense of scalability. These platforms, which consist of about 10,000 to several tens of thousands of nodes, have a very low Transaction Per Second (TPS) of around 10, which is a bottleneck in the execution of frequent transactions. Therefore, solving scalability in public blockchains has become a central issue in research and development (JST 2019).

On the other hand, as already mentioned, since the Moonshot Goal envisions a platform where participation itself is the motivation, anonymous participants outside of the stakeholders are not assumed. However, it is necessary that the TPS can withstand the expansion of the platform's scale, so research and development is required to solve the trade-off between scalability and security. **Table II-2-1** shows a comparison of typical performance of blockchains that are currently possible candidates and that can be operated in a consortium type.

Table II-2-1: Performance comparison of blockchains that are potential candidates for the Moonshot Goal.

	Rheia	Hyperledger Fabric	Go Quorum	Substrate	Cosmos	Corda	Solana	Avalanche Network	Hedera Hashgraph	miyabi
コンセンサスアルゴリズム	Proof of Convergence	PBFT (election type) Raft / Kafka / Solo (Orderer)	IBFT Raft Clique	Aura (round robin) BABE (slot-based) PoW Customize	Tendermint BFT	Raft BFT-SMaRt	PoH Tower BFT	Avalanche Consensus	Hashgraph PoS	BFK2
ノードの役割	全て同等権限	リーダーノード/フォロワーノード 動的な投票	提案 / 検証 リーダー / フォロワー / 習熟者メーカー	検証ノード	検証ノード	ノタリーノード	リーダーノード / 検証ノード 非同期ローテーション	検証ノード	検証ノード ブロック生産者	リーダー / フォロワー (動的な投票)
ファイナリティ	1~4 秒	数秒～17秒	1~4 秒	最長鎖ルール or ゴーストルール	1 秒	1~4 秒	0.4 秒	0.206 秒	3~5 秒	1~4 秒
セキュリティに関する優位性	単一障害点の排除	決定論的コンセンサス チャンネルシステム	プライベート状態	セキュリティ共有	フォーク時に明確な責任所在	データ秘匿	セキュリティ会社による監査	>51%の保証	単一障害点の排除 コンセンサス順序が証明可能	決定論的コンセンサス
Max TPS	31,240	2,700	900	数千 (推定)	数千	22000 (平均 6,300)	50,000	7,002	10,000+	4,000
ノードスペック	512 MB RAM	PC Spec	PC Spec	PC Spec	PC Spec	PC Spec	GPU	PC Spec	PC Spec	16GB RAM
他のチェーンとの相互互換性	✔	–	✔	✔	✔	✔	✔	–	–	–
国産	✔	–	–	–	–	–	–	–	–	✔

"RHEIA," A DOMESTIC PROTOCOL, ACHIEVES A BREAKTHROUGH

As shown in Table II-2-1, **Rheia achieves a fast and secure blockchain by combining a very high level of scalability and security at the moment.** In terms of transaction speed, it reaches 31,240 TPS (benchmark) with 240 nodes and 28,936 TPS with 10,000 nodes. In terms of security, the system has succeeded in eliminating single points of failure through a mechanism in which all nodes have equal authority to verify transactions and consensus on blocks. This means that a truly democratized, decentralized, and public-like platform can be formed, even though it is consortium-based. Another advantage of Rheia is that it is highly customizable compared to other chains. This is because Rheia is a completely original blockchain protocol (Layer 1 blockchain). This allows for development that is not bound by external factors and flexible implementation of functions, unlike technologies that add on to an existing chain (Layer 2 blockchain). For example, as the platform expands, it can be implemented in a very flexible manner, such as requiring approval for the addition of nodes and setting its own approval rules, specifying detailed permissions for viewing data, and freely setting the format of data to be retained. In addition, the small specification required for the server that operates the node means that the required resources are small, indicating that Rheia is a protocol with low environmental impact.

Rheia is a blockchain invented by Kenta Iwasaki and supported by the company, but it is expected to be fully open sourced in 2022, which will expand the scale of the developer community.

RELATED R&D CHANGES

Figure II-2-2 shows the genealogy and future prospects of blockchain technology. As already mentioned, blockchain technology is a complex elemental technology. The underlying technologies, such as cryptographic protocols and P2P networks, have a history of more than 30 years in the field of computer science. On the other hand, the possibility of cryptanalysis by quantum computing has been discussed in recent years, and at the same time, the development of more robust cryptography called quantum cryptography has been progressing (for example, in Japan, a demonstration experiment to transfer genome information via quantum cryptography communication has been successfully conducted. https:// ps.nikkei.com/toshiba2103/ryoshi/index.html)

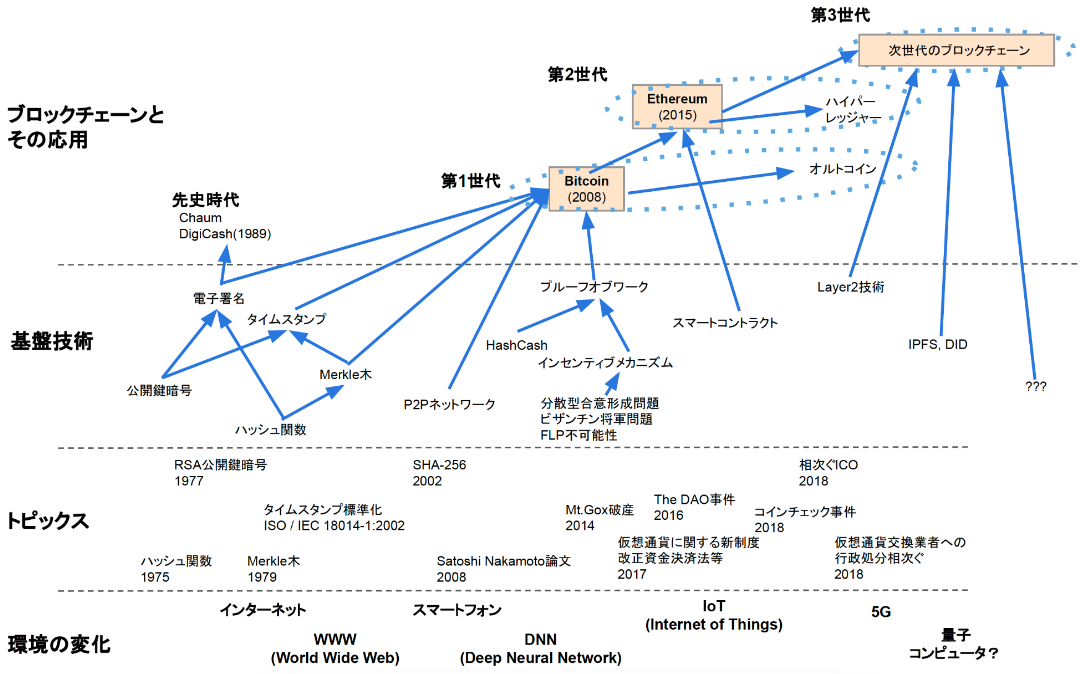


Figure II-2-2: Genealogy and Future Prospects of Blockchain Technology (Processed from p.18 of the JST Center for Research and Development Strategy (JST/CRDS) 2019 Strategic Proposal "Next Generation Blockchain Technology - Secure and Reliable Data Sharing and Value Exchange for Individuals and Society" (JST 2019))

b. To achieve ocean visualization

CHALLENGE OF VISUALIZING THE OCEAN

The vast oceans have low visibility and high spatio-temporal variability. Reducing the uncertainty of the ocean, or accurately understanding the magnitude of uncertainty, is an urgent issue in ocean utilization.

In this section, we will consider the issues that need to be overcome by science and technology in the area of ocean visualization, and divide them into three categories: (1) "ocean observation and understanding of ocean use," which is the process of collecting and integrating ocean and ocean use data; (2) "evaluation of the current state of the oceans and future predictions" through modeling with the data; and (3) "ocean visualization for communication," which makes ocean information available to the general public.

Ocean observation and understanding of ocean use

For the purpose of ocean visualization, the technology to observe and collect data from the ocean is important. While the central issue is to motivate people to collect data in our MS goal, it is also desirable that the technology for collecting data itself continues to develop.

The acquisition of oceanographic data to visualize the ocean is difficult because the area and period of time in which the vast and ever-changing ocean can be directly observed on the Earth's surface are limited, and such direct observation by ships and other means requires enormous costs.Our Moonshot Goal is to solve this problem not by acquiring data at huge cost, but by motivating data collection through wealth accumulation and encouraging marine industry workers to collect and share data on their own.

On the other hand, earth surface observation by space satellite networks, or remote sensing, enables us to acquire ocean data over a wide area and continuously. Although global macroscopic data is effective for macroscopic ocean visualization such as climate change and ocean acidification, it is not easy to directly link such macroscopic data to ocean utilization as an economic activity. It is important to integrate microscopic data collected independently by marine industry workers and macroscopic data obtained by remote sensing technology for providing useful information for marine industry and knowledge that can serve as a basis for long-term policy decisions. Through the integration of the data, the value of macroscopic data can contribute to the optimization of ocean use, and provide incentives and investments in the collection of these data. This point will also be discussed in "Ocean Visualization for Communication.

ASSESSMENT OF THE CURRENT STATE OF THE OCEANS AND FUTURE PROJECTIONS

No matter how much progress is made in data collection, we will never realistically be in a situation where "all physical, biological, and social elements of all the oceans of the earth are understood at intervals of one millimeter," nor is there any need for such a situation. Nor is it possible to collect data for the future. Simply collecting data will make it invisible, even to places one millimeter away or one second into the future. True visualization also targets places and things that will happen in the future for which no data has been collected.

In order to perform geographic interpolation and temporal prediction, we will build models that correspond to natural phenomena. This requires continuous development in understanding and predicting natural phenomena by analyzing data. Although the use of data generated by ocean use and prediction using machine learning and other methods has been gradually gaining popularity in recent years, there is still a great deal of room for growth. The development of new visualization technologies using explainable AI will be a breakthrough in this field. It is also necessary to develop modeling techniques based on a deep understanding of ecosystems, rather than constructing models on an ad hoc basis. Using models that include random effects to understand what stochastic processes govern organisms is also an important visualization technique. Currently, modeling technology for describing processes, AI technology for improving prediction accuracy, and models for describing stochastic processes are being developed separately, but for ocean visualization, integrated modeling technology that integrates these three modeling technologies will be a breakthrough in this field.

OCEAN VISUALIZATION FOR COMMUNICATION

Converting ocean and ocean use data into meaningful information through ocean visualization alone will not lead to ocean utilization. Only by delivering the information obtained through visualization as "live" information to the general public, who do not have specialized knowledge, can we achieve the expansion of ocean use and the optimization of ocean use.

Universal communication technology in the field of informatics is a technology that removes barriers between various types of information and their users (Kibawara 2015). Ocean visualization encompasses this universal communication technology. This technology will be touched upon again in (3) Optimizing the use of the ocean, since it depends greatly on the values and purposes of the users of the information.

c. To optimize the use of the ocean

INDIVIDUAL DECISION-MAKING CHALLENGES

Even if the wealth accumulation of the oceans, and the visualization facilitated by the wealth accumulation, is achieved, it does not mean that all the problems associated with the use of marine resources will be solved. For example, fishermen will only be confused if they receive the huge amount of data obtained by visualization as a numerical table. Based on the knowledge of data science and decision science, it is necessary to formulate a function, or decision method, to convert the huge amount of data into action.

CHALLENGES OF SOCIAL DECISION MAKING

Even if the visualization of the oceans were to eliminate uncertainty, the challenges of social decision-making would still remain. The realization of ocean wealth accumulation and visualization would provide a framework for individuals to capitalize on and use ocean resources at the optimal time and in the optimal way. But who will benefit from the new resources created there? Historically, the ocean has been positioned as a non-excludable and competitive public good, or common resource good, and as a result it has been subject to competition and deprivation, and the potential benefits of ocean resources have been lost. This is known as the tragedy of the commons. In order to protect marine capital from the tragedy of the commons, a "mechanism" is needed to create a new form of use that enables sustainable use and is based on consensus among stakeholders, rather than leaving it as a public good.

Challenges posed by uncertainty in social decision making

Of course, even if we promote the visualization of the ocean, we still cannot completely reduce the uncertainty of the natural environment to zero. The higher the future uncertainty (uncertainty), the higher the discount rate, and the more we consider only immediate benefits (Ostrom et al. 1999; Gutiérrez et al. 2011). Decisions about ocean use must be subject to uncertainty and risk. There is an urgent need to overcome the challenges of designing social institutions and improving the decision-making process under these institutions in marine resources, where uncertainty and competition are inevitable.

Issues related to utility aggregation

For example, let's consider expressing the degree of desirability or happiness that an individual considers as a numerical value as utility, and maximizing the total amount of this value. When considering whether to use a certain area for fishing or aquaculture, conflicts about land use arise. If we adopt the decision-making procedure of "giving priority to the interests of the majority" in order to increase the number of people engaged in the marine industry, the minority group will always be oppressed. In ethics, the trolley problem asks whether it is right or wrong to kill one person to save five lives, but essentially the same problem can always arise in social decision making.

BREAKING THE "PANACEA" ILLUSION

The above problem formulation has been actively discussed in social choice theory. Suppose that people have their own personal order of social states: which social state is the most preferable to the social state to be selected (e.g., land use method or fishing quota in a given year), and which social state is the next most preferable. On the other hand, the order of social states that are preferred by society, not by individuals, is called the social order. The process or rule that determines a social order for every pair of individual orders among all stakeholders is called a social welfare function. In this case, it is known as Arrow's impossibility theorem that there is no social welfare function that satisfies completeness, transitivity, unanimity, binomial independence, and non-dictatorship. There is no rule of social decision making that has all the properties that the required social welfare function should have (Arrow 2013; Sakai 2013).

However, by loosening some of the axioms required by Arrow's impossibility theorem, various rules of social decision-making have been produced (Shida 2016). It can be said that the ambiguous subject of social decision-making has been discussed within the framework of science, and the groundwork has been laid for clarifying the problem and improving the rules of decision-making.

In order to optimize the use of marine resources, it is necessary to apply the framework of social choice theory to optimize individual behavior, design an ideal social system, and establish rules for social decision-making. In the optimization of individual behavior, it is necessary not only to predict the future based on accumulated data, but also to develop semi-automated decision-making methods using the results of predictions, as well as technology for formulating optimal strategies based on the estimated balance of supply and demand and the magnitude of risk.

On the one hand, it is not realistic to propose an "impeccable" social welfare function in social choice. Even in fisheries management, there has been an illusion of a "panacea" with unconditional faith in certain policies (Young et al. 2018). The real role of science and technology is to shatter the illusion of a "panacea," rather than to string together palatable terms that have proven to be unattainable.

BREAKTHROUGHS IN SCIENTIFIC POLICY EVALUATION

The breakthrough technology is the development of protocols to evaluate the consequences of new institutions and new social systems as an improvement of the science-backed procedures of social choice. Rather than proposing an "impeccable" social system, a game-changing change from sterile debates can be achieved by shifting to an approach that aims to "enable people to understand quantitatively and scientifically the good and bad of a social system and to make choices based on that understanding”. In fisheries management, management strategy evaluation (MSE; Punt and Donovan 2007, Ichinogawa and Okamura 2016) using extensive simulation has been applied in practice with great success (Hillary et al. 2016). The application of simulation-based policy evaluation, starting from fisheries management to the broader use of marine resources in general and social system design in particular, is the only Challenging yet Credible solution to achieve the optimization of ocean use.

3. Japan’s position in overseas trends

a. To realize the wealth accumulation of the oceans

Figure II-3-1 shows a bird's eye view analysis of papers related to blockchain. As already mentioned, attempts to solve the trilemma of scalability, security, and centralization account for a large percentage of the papers (corresponding to the "four basic challenges" section in the figure). In other words, it suggests that the challenges that we try to address for the Moonshot Goals are related to the essence of blockchain. IoT applications tend to be studied in connection with the solution of the trilemma, as papers on IoT applications necessary for the application of blockchain to the marine industry are included in the "Four Fundamental Challenges".

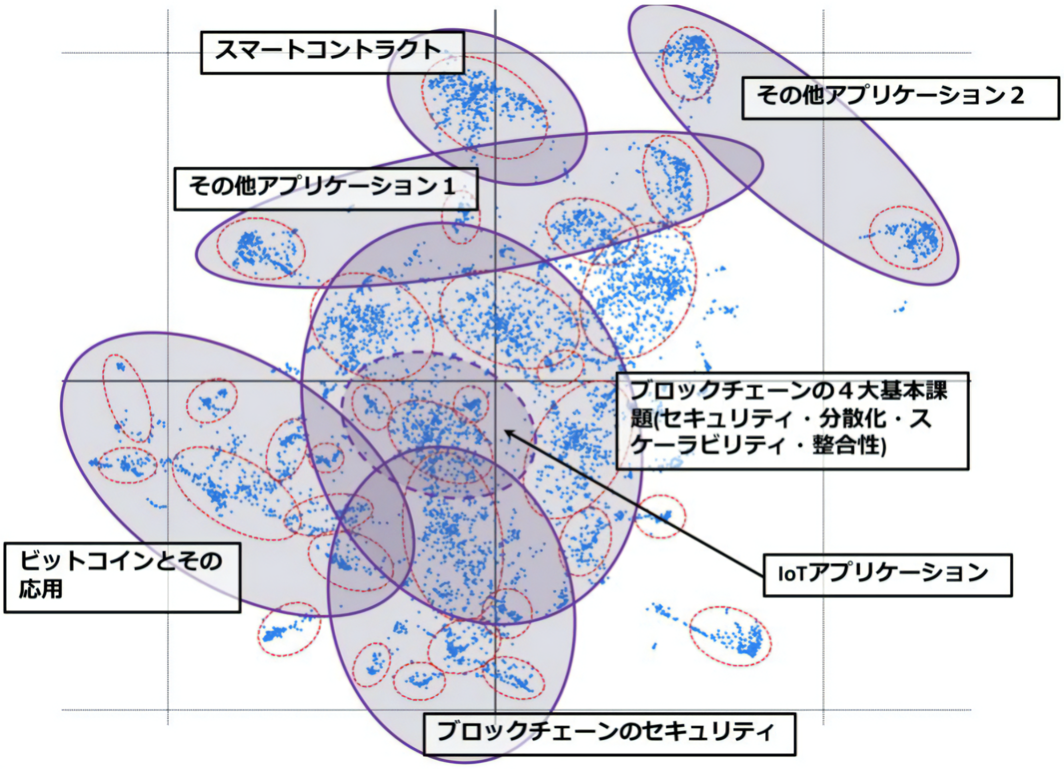


Figure II-3-1. Overhead analysis diagram of papers related to blockchain.

Each paper is arranged according to the similarity of the text. adapted from p. 34 of the JST Center for Research and Development Strategy (JST/CRDS) 2019 strategic proposal "Next-generation Blockchain Technology - Secure and Reliable Data Sharing and Value Exchange for Individuals and Society" (JST 2019).

Table II-3-1 is a table of international comparisons of blockchain technologies. Japan's vitality has been maintained, with notable activities and achievements visible in all faces. This Moonshot Goal encompasses a plan to gain a comparative advantage in the field of blockchain technology by leveraging basic research and conducting applied research to apply the results to marine-related industries.

Table II-3-1. International comparison of blockchain technology (extracted from p.485-487 of the JST Center for Research and Development Strategy (JST/CRDS) 2021 “Overview Report on Research and Development.”)

ブロックチェーン技術の国際比較

国・地域	日本		米国		欧州		中国	
フェーズ	基礎研究	応用研究・開発	基礎研究	応用研究・開発	基礎研究	応用研究・開発	基礎研究	応用研究・開発
現状	○	○	◎	◎	○	◎	○	◎
トレンド	→	→	→	→	→	↗	→	↗

（出典）JST CRDS 研究開発の俯瞰報告書　システム・情報科学技術分野（ 2021）
（註 1）フェーズ　基礎研究フェーズ：大学・国研などでの基礎研究の範囲
応用研究・開発フェーズ：技術開発（プロトタイプの開発含む）の範囲
（註 2）現状　※我が国の現状を基準にした相対評価ではなく、絶対評価である。
◎：特に顕著な活動・成果が見えている、○：顕著な活動・成果が見えている、
△：顕著な活動・成果が見えていない、、×：活動・成果が見えていない
（註 3）トレンド　↗：上昇傾向、→：現状維持、↘：下降傾向

b. To achieve ocean visualization

JAPAN'S ADVANTAGE IN CLIMATE CHANGE MODELING

Table II-3-2 is extracted from the JST Center for Research and Development Strategy (JST/CRDS) 2021 "Overview of Research and Development Report (JST 2021)", showing an international comparison of research and development areas that overlap with ocean visualization technologies. In terms of basic research in the field of climate change prediction, Japan is considered to have high potential in the research community, with several institutions independently developing climate models (GCMs) and earth system models (ESMs) that predict global changes in the global environmental system. On the other hand, in the field of applied technology for ocean observation, there have been no significant activities or results because there has been almost no development or commercialization of the hardware necessary for automated observation platforms, and it is concluded that it is necessary to establish domestic collaboration and international cooperation.

Table II-3-2 International comparison of research and development status (JST 2021, excerpted from Table 2.1-1 in the field of climate change prediction)

	Country / Region	Japan		America		Europe		China	
	Technology Phase	**basis**	**application**	**basis**	**application**	**basis**	**application**	**basis**	**application**
Climate Change Observation	satellite	○↘	○↘	◎→	○→	◎→	◎→	△↗	○↗
	Atmosphere and land	○↗	○→	◎↗	◎→	◎↗	◎↗	○↗	△→
	ocean	○→	△→	◎→	◎→	◎→	△→	○↗	△→
Climate Change Prediction		◎→	○↗	◎→	◎↘	◎→	◎↗	△→	△↗
Observation, evaluation, and prediction of ecosystems and biodiversity		○→	○→	◎↗	◎↗	◎↗	◎↗	◎↗	◎↗
Assessment and prediction of social and ecological systems		○↗	○↗	◎↗	◎→	◎↗	◎↗	○↗	◎↗

In order to apply Japan's strengths in climate models and earth system models, which predict global changes in the global environmental system, to ocean visualization for ocean utilization, it is necessary to increase the resolution of ocean data through continuous and comprehensive automatic ocean observation platforms, which is an application technology of ocean observation that Japan is not good at.

From Climate Change Models to Ecosystem Models, Japan has been a leader in the field of "fisheries oceanography", which studies the impact of climate change on the variability of fisheries resources (Inagake et al. 2013). Small pelagic fish stocks such as mackerel and sardine, which make up a large part of Japan's marine products, have historically fluctuated significantly with decadal-scale changes in the marine environment (Kawasaki 2007), making research to link marine environmental changes with biological processes and population dynamics (c.f. Takasuka et al. 2008). For these studies, research vessel surveys to estimate egg densities of marine organisms have been conducted in the waters surrounding Japan for more than 40 years, and the resulting data sets (c.f. Takasuka et al. 2008) are one of the best quality and quantity in the world.

On the other hand, it has been pointed out that Japan's fishery resources continue to be subjected to significant external pressure from fishing as well as marine environmental changes, and as a result, many of Japan's fishery resources are at lower than appropriate levels (Ichinokawa et al. 2017). The fact that current levels are low suggests the possibility of a significant recovery of resources in the future (Tokunaga et al. 2019), and in fact, mackerel and sardine stocks are on a recovery trend (Ichinokawa et al. 2015).

The experience that the populations of marine organisms in the waters surrounding Japan have fluctuated greatly depending on the environment and fisheries, and the marine organism research network that has been established in Japan, is an advantage in assessing the parameters of how the populations of marine organisms are affected by external pressure.

IMPROVING MODELING TECHNIQUES

Furthermore, the improvement of computer performance and optimization techniques for modeling is another major change in recent years. In order to estimate a model parameter, some optimization calculation is often performed, for example, to minimize the residual sum of squares or maximize the likelihood. At this point, the performance of the optimization software will affect the efficiency of the modeling process, and thus the feasibility in a realistic amount of time. With the recent advent of software called Template Model Builder (TMB, https://kaskr.github.io/adcomp/Introduction.html), which rapidly searches for maximum likelihood estimates of parameters by automatically differentiating the likelihood function, the complexity and flexibility of the models that can be estimated has increased dramatically. This has made it easier to estimate the distribution density of marine organisms using a modeling method that takes into account spatio-temporal autocorrelation (Thorson and Barnett 2017). This method has been applied to the aforementioned egg density data of marine organisms in the vicinity of Japan, and is producing significant results, such as the elucidation of long-term changes in the spawning grounds of mackerel (Kanamori et al. 2019).

c. Optimizing the use of the ocean

BACKGROUND AND PRESENT OF SOCIAL CHOICE THEORY

The theory of utility that forms the basis for understanding the nature of decision-making and decision support is called utility theory. The origins of utility theory can be traced back to Bernoulli's argument against the St. Petersburg paradox (Tamura et al. 1997), but its development is largely due to the formulations by Neumann and Morgenstern (von Neumann and Morgenstern 2009). Although there have been many counterexamples to attempts to formulate human values based on expected utility theory, the development of alternative theories, such as prospect theory and Maximin expected utility theory, has advanced our understanding of the description of human behavior and the norms of behavior that should exist (Gilboa 2014). Recently, attempts to describe human values using large-scale data and neural networks have also been advanced (Peterson et al. 2021).

In the late 1700s, Borda and Condorcet raised the issue of majority rule, which played an important role in the birth of social choice theory (Sakai 2013).After some time, it was formulated through Arrow's monumental work published in 1951 (the Japanese translation of the third edition was published in 2013 (Arrow 2013)). For this reason, it is relatively new as an academic field. The first contribution that social choice theory has made is the full use of mathematics in its grounding (Shida 2016). It formulated the ambiguous subject of social decision-making and gave it a form as a discipline.

KNOWLEDGE ACCUMULATION IN THE WORLD & JAPAN'S SUPERIORITY

On the other hand, various theories and methodologies for the optimal use of the ocean have been proposed in the field of problem solving for individual cases. However, since the use of natural capital is realized as a result of complex interactions between large-scale natural and social systems, it is impossible to prove the validity and appropriateness of theories and methodologies through repeatable experiments. For this reason, research on theories and methodologies of optimal use can be broadly divided into 1) meta-analysis (e.g., Worm et al. 2009; Gutierrez 2017) (Table II-3-3), which evaluates the effect of the system when it is actually introduced into society and accumulates the findings, and 2) simulation research, which describes the behavior of natural and social systems. MSE (Punt and Donovan 2007), which describes the behavior of a system by simulation and repeatedly applies management measures in virtual reality.

Table II-3-3 summarizes the management practices that were found to be effective for sustainable resource use, referring to Worm et al. (2009) and Gutierrez (2017), and compares them within and outside Japan. In addition, the mechanism by which these measures work effectively is indicated in the "mechanism" row, with the "effectiveness" quoted from Worm et al. (2009). While Europe and the United States have many empirical examples of the effectiveness of fishing quota systems that evoke economic incentives (Chu 2009), **Japan has a wealth of empirical examples based on the fishery cooperative system as community management, and this is one of Japan's great strengths. This is one of Japan's great strengths. Therefore, taking up Japanese fishery resource management and using it as a starting point to address the issue of decision-making in natural resource use is a research task that only Japan can undertake.** In addition, many of these resource management measures can be expected to have a synergistic effect with highly institutionalized resource assessment (ocean visualization). Japan's resource assessment technology within the framework of ocean visualization may not be the most advanced, but it has accumulated data and knowledge over a long period of time, and has ample potential to make a leap forward.

Table II-3-3**: Domestic and international trends in empirical and social implementation examples of sustainable use methods for marine resources as a commons.** There are many prior research examples on institutional design and consensus building methods for sustainable use of the commons, especially in the field of marine resource use, and this table also summarizes the results of meta-analysis in marine resource use (Worm et al. 2009; Gutierrez 2017). This table summarizes the results of meta-analyses in fisheries resource use (Worm et al. 2009; Gutierrez 2017). columns for effectiveness are relative values taken from Worm et al. (2009) except for data availability, where higher values indicate higher effectiveness. 2017). Individual methods are not mutually exclusive, and management is usually implemented through a combination of several. Those that complement each other with the concepts proposed in this project (wealth accumulation and ocean visualization) are described in the "Characteristics" section. For general characteristics of each method, we refer to Cochrane and Garcia (2009); for overseas trends, we refer to Hilborn and Hilborn (2012); for Japanese trends, we refer to Makino (2011) and the Fisheries Agency website. For the area of protected areas in overseas countries, I referred to the Global Biodiversity Overview (5th edition) (Secretariat of the Convention) and the Ministry of the Environment website (Ministry of the Environment, Japan). (2011) and the Ministry of the Environment website (Ministry of the Environment 2011).

Institutional and consensus building methods	mechanism	effectiveness	Features	Overseas Trends	Trends in Japan
Restrictions on fishing methods and gear (Gear restrictions)	regulation	14	Relatively easy to implement, but at the expense of economic efficiency due to restrictions on how efficiently it can be fished.	Used in areas where TAC is difficult to apply.	Used in community management
Limiting investment in increased fishing effort (Capacity reduced)	regulation	10	Relatively easy to implement, but at the expense of economic efficiency due to restrictions on how efficiently it can be fished.	Used in areas where TAC is difficult to apply.	Used in community management
Catch limits (TAC reduced)	regulation	18	If the resource assessment is appropriate, it will be highly effective. Synergistic effects with ocean visualization can be expected.	The United Nations Convention on the Law of the Sea requires that fishery resources in the EEZ be managed by TACs. In the United States and Europe, TACs have been established for many fish species.	The revised Fishery Law will expand the number of TAC managed fish species to 200.
Setting upper limits on fishing effort (TAE reduced)	regulation	5	Problems of changes in human behavior, such as increased fishing effort in unregulated areas, were pointed out.	long vowel mark (usually only used in katakana)	Used in community management
Establishment of protected areas (Closed areas)	control	15	It is important to set up a protected area in an appropriate location and period. Synergistic effects with ocean visualization can be expected.	Approximately 7.5% of the sea area by 2020	As of 2010, the percentage was 8.3%. Many of these areas are fishing rights areas designated by the Fisheries Law.
catch quota (Catch shares)	economic motive	14	By making rights privately owned, economic incentives are stimulated, and maximizing individual benefits also maximizes society's benefits. The disadvantage of this approach is that it is expensive to manage, as it is necessary to monitor the compliance of each individual with the quota. However, the research plan of this project suggests the possibility of reducing the management cost by using blockchain for allocation (synergistic effect with wealth accumulation).	United States, New Zealand, Norway	Introduced on a trial basis in some fisheries, and specified in the revised Fisheries Law.
Marine Products Certification System (Fisheries certification)	transparency economic motive	3	Consumers' selective purchasing motivates them to fish in a sustainable way.	Cooperation with MSC and other supply chains that handle only MSC certified seafood	MEL, Sh "u "n Consumer awareness is not significant.
community management (Community co-management)	exclusive use impartiality	8	Exclusive use, consensus building within the community	Chile (territorial use rights in fisheries, TURFs)	Fishing cooperative system (Japan's strength)

III. Plan for Realization

1. Area and field of challenging R&D, research subject for realization of the Goals

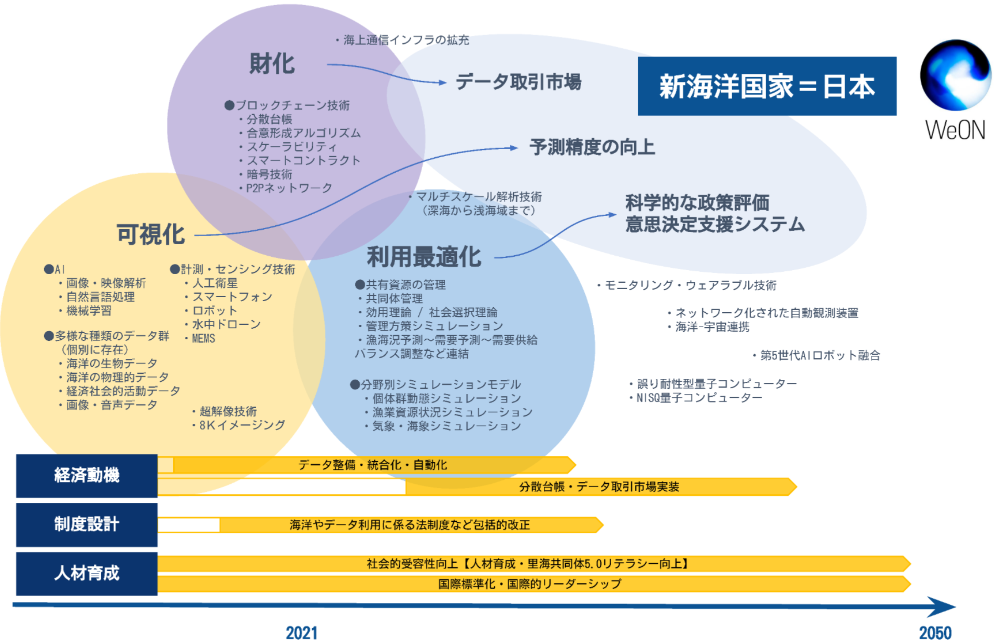


Fig.III-1. Technical overview to achieve the Moonshot goal

a. To promote the wealth accumulation of the oceans: Ensuring Scalability of Blockchain and Application of Blockchain to the Marine Industry

Separate research topics for Layer 2.5 and below and for Layer 3.0 and above to overcome them. The research challenges for Layer 2.5 is (A) to ensure the scalability of the blockchain. There are two research topics for Layer 3.0 and above: (B-1) designing a market that enables secure online automated trade of goods originating from fisheries, and (B-2) coordinating and controlling supply chains for fisheries. The specific research topics for each are listed below.

RESEARCH TOPIC 1-A: ENSURING SCALABILITY OF BLOCKCHAIN

Ensuring the scalability of blockchain for use in the marine industry across the country

The goal is to eliminate the trade-off relationships that prevent scalability. Trade-offs refer to the relationship between speed (processing performance per second), security, and required specifications, where one is sacrificed for the other.

Layer 0

- Development of a highly efficient protocol for all nodes to recognize the transaction in a short time.
- Development of coordination algorithms to spread information to all nodes in a short time.
- Development of control algorithms to parallelize the block authentication process.

Layer 1.0

- Development of a sampling algorithm to perform block authentication in a short time.

Layer 2.0

- Improving the efficiency of data structures to increase the speed of access processing at each node.
- Efficient partition design and development when handling data across multiple blockchains.

Layer 2.5

- Development of a cryptographic signature scheme to verify multiple transactions in a short period of time.

RESEARCH TOPIC 1-B: APPLICATION OF BLOCKCHAIN TO THE MARINE INDUSTRY

Research and development will be conducted to overcome scalability issues and to apply blockchain to the marine industry with secure, fast, and energy-saving transaction functions. The second issue is linked to "Research Theme 3: Optimisation of Ocean utilization" and will contribute to the sustainable use of the ocean.

1. Designing a market for secure, automated online trading of goods originating from fisheries.

- Decentralized management of ocean-related data, information, usage rights, and values
- NFT (Non-Fungible Token) conversion according to the content of rights

- Assigning IDs to property owners by turning their biometric devices into nodes
- Implement a system for setting detailed access rights.
- Smart contracts to transfer goods and complete transactions under certain conditions.

2. Coordinate and control the supply chain for fisheries.

- Decentralized management of data and information generated in the supply chain
- Biometric (image, compound, genome) traceability of fish catches
- Assigning IDs by turning IoT (Internet of Things) into nodes
- Smart Contract Design Linked to "Research Theme 3: Optimisation of Ocean utilization
- Automatic coordination and control in each IoT by smart contracts

  * NFT: Non-Fungible Token: A non-replaceable token that is tracked on the blockchain and provides the purchaser with proof of entitlement to hold it.
  * IoT: Internet of Things: A system in which various "things" are connected to the Internet and mutually controlled by exchanging information.

b. Ocean visualization: Development of technologies that will dramatically expand the visualization of the ocean

RESEARCH TOPIC 2-A: DEVELOPMENT OF MODELING TECHNOLOGY FOR OCEANS AND MARINE ECOSYSTEMS

In order to achieve a wide range of interpolation and prediction of marine and biological data, we will develop a wide-area modeling technique that takes into account the interaction of multiple fish species. In modeling, we will develop a flexible modeling method that combines the state-space model and maximum entropy method with the latest AI technologies such as deep learning and explainable AI. There are three main points of modeling in this technology development theme: first, focusing on modeling to promote understanding of the process of the phenomenon, second, combining it with stochastic models to evaluate uncertainty, and third, compensating for the heterogeneity of data quality by AI technology.

As for the second stochastic model, its feasibility is ensured by the background that recent software development for computational performance and high speed computing has made it possible to estimate models with complex error structures (see II-3 of this report). In the past, it took a lot of time and effort to estimate models with random effects. However, in the current situation, much of this problem has been solved. Various modeling methods have been proposed, including not only the maximum likelihood method but also the combination of Bayesian inference and MCMC. Using these techniques, this research visualizes the magnitude of uncertainty accurately by means of a stochastic model. The results of the visualization will lead to optimized utilization. In order to achieve the goal of providing information that can be easily used for decision making, uncertainty visualization is an important technology that cannot be ignored.

The third point, AI technology, is based on the fact that the data available in the future will become big data due to the wealth accumulation of data, which is fulfilled in Research Theme 1. With the wealth accumulation of data, more data of various quality and quantity will be available than ever before. For example, data available for the elucidation of marine living resources could include survey, catch, satellite, and market transaction data. When such a wide variety of data becomes available, we will be dealing with a large amount of data that represents the same phenomenon with different resolutions and accuracies. First of all, it is important to develop a hierarchical model that extracts data with useful information from the large amount of data using AI technology, etc., and then model the process to understand it. For this purpose, a flexible combination of the latest AI technology and traditional modeling technology is the key. In addition, causal inference techniques and explainable AI should be actively used for modeling to understand the first process. By consciously combining these three points, we will develop a new set of technologies, including the visualization of the reasons why natural phenomena fluctuate.

c. Optimizing the use of the ocean: Development of technologies to promote optimal use of the ocean

Promote the development of science and technology to achieve optimization of ocean use based on the results of ocean visualization. Research and development will be conducted not only to optimize individual decision making, but also to improve social decision making.

Research Topic 3-A focuses on individual decision-making and attempts to develop specific social implementations to support decision-making. Issue 3-B is to develop protocols for evaluating social decision-making and institutions, and Issue 3-C is to design and evaluate a specific social system for marine resource management.

RESEARCH TOPIC 3-A: DEVELOPMENT AND SOCIAL IMPLEMENTATION OF TECHNOLOGIES FOR OPTIMIZING INDIVIDUAL DECISION MAKING

In order to support individual decision making based on the assumption that there is risk and uncertainty, we will develop a decision-making system that inputs the results of ocean visualization and outputs the actions to be taken. Then, for fishermen, we will develop a decision support system that links fishing condition prediction, demand prediction, and demand-supply balance adjustment. This system will provide information to determine when and when not to fish. For this issue, we will not only model but also create and demonstrate a minimum viable product (MVP) in a specific region.

The results of this research will be of direct benefit to fishermen. The results of benefiting from the use of data should provide an economic incentive for fishermen to release and share their data. Through questionnaires to fishermen and empirical experiments, we will clarify whether those who benefit from the use of data actually feel compelled to provide data.

RESEARCH TOPIC 3-B: DEVELOPMENT OF SIMULATION-BASED EVALUATION PROTOCOLS FOR SOCIAL SYSTEMS AND THEIR SOCIAL IMPLEMENTATION

On the subject of fishery resource management, we will develop and socially implement an evaluation protocol for comparing multiple alternative social systems (fishery management measures). In doing so, we will explore the correspondence between the values of stakeholders and the rules to satisfy those values. For example, the possibility of achieving equality of opportunity or equality of outcome when a certain system is applied, the total monetary value generated, or the magnitude of annual variation in wealth, etc. We will clarify the correspondence between what values are prioritized and what system is appropriate.

As a method, we will use simulation-based evaluation of social systems, the so-called MSE, and develop the infrastructure to implement it. In the long term, we will evaluate various systems that do not fit into the MSE in virtual reality, where simulation and real data are integrated in the framework of data assimilation. Specifically, we will evaluate systems such as catch quotas in the fisheries sector and the impact of mid-term revisions to the TAC.

As soon as the technological development to evaluate the features of the systems already under consideration is completed, we will move on to the evaluation and verification of the new social systems. Specifically, we will attempt to evaluate the proposed social system in Research Project 3-C. In the long term, we will provide such simulation-based policy evaluation as a general protocol to facilitate evidence-based policymaking (EBPM) and decision-making within regional communities on various future issues with high uncertainty.

The technical difficulty of this research project varies depending on the policy to be evaluated. Initially, we will try to evaluate and solve relatively simple problems that have high social value, and then gradually increase the scale of the project to eventually include the ambiguous subject of evaluating social systems. In this sense, this research project is scalable and can be expected to develop over the long term.

RESEARCH TOPIC 3-C: PROPOSAL OF A NEW MECHANISM FOR RESOURCE UTILIZATION

To create and study the effectiveness of mechanisms for the optimal and sustainable use of extensive marine resources in society.

Since it is difficult to exclude users of marine resources and there is competition for their use, there is always the danger of a phenomenon called the tragedy of the commons, in which each user behaves rationally, and as a result, overall efficiency is not achieved. This tragedy of the commons is said to be responsible for the collapse of shared resources, including marine resources, that is occurring around the world. On the other hand, Eleanor Ostrom, who was awarded the Nobel Prize in Economics for her theoretical and empirical research, pointed out that shared resources do not necessarily collapse, and that there are many cases in the world where they are properly managed by the self-management of local communities. Ostrom's empirical research includes the co-management of fisheries by Japanese fishery cooperatives, and in particular, she points out that they manage areas beyond the control of the central government by setting their own rules through autonomy.

Some studies suggest that the incentives for co-management by Japanese fishing cooperatives are the result of the emphasis on "fairness" within the community (Tokunaga et al. 2019). Community management includes territorial use rights for fisheries (TURF), which gives individuals or groups the right to harvest within a certain geographic area, and cooperative management, which gives a group of people a use ticket in exchange for managing the resource (Costello 2012).

On the other hand, in areas where community management has not historically been practiced, rights-based management is a management system that grants the right to use resources to individuals or groups. A representative example is the individual harvest quota (e.g., individual catch quotas in fisheries), in which the amount of resources harvested is set as a right before harvesting and distributed to each individual. Right-based management is a system in which the maximization of individual profits leads to the maximization of overall profits. However, it has been reported that making the rights tradable has some drawbacks, such as the elimination of small fishermen and the collapse of local communities. In particular, if the Ocean Cycle creates new values in the ocean, the question is who will benefit from the new values. While this requires a rights-based management approach that avoids the tragedy of common land, it also requires devising institutions that take advantage of the intangible common property protocols of trust and norms that exist in local communities. However, in recent years, the limitations of individual quotas have been pointed out, and there have been discussions about policy-driven attempts to create a system that grants rights to groups and communities for management and use. (Holland 2018). The co-management that exists in Japan is a method of using shared resources that has been formed over a long history, and has a history of the government retroactively granting rights to communities that existed. However, from now on, it is necessary to recognize that intangible common property protocol and redesign the system.

Our idea of a "new mechanism for resource utilization" is based on the world-class regional community management that Japan has established, but also incorporates the advantages of right-based management that stimulates economic motivation. This will be the core of the Satoumi Community 5.0, which will use marine natural capital in a sustainable and consensual manner, based on local seas rooted in the local climate. This proposal will be evaluated and brushed up in the simulation-based institutional evaluation protocol constructed in 3-B.

2. Direction of R&D for realization of goals

Our goal is to drive the cycle of ocean wealth accumulation, visualization, and optimized utilization with economic motivation by 2050, and to realize a new Ocean Nation, Japan. Based on this, the short-term goal is to be achieved between 2021 and 2030 as MS research and development. The year 2040 was set as a medium-term target for evaluation and revision at the midpoint between 2050, when the ideal is to be realized, and 2030, when it is to be realized through steady research and development.

a. Ocean Wealth Accumulation

RESEARCH TOPIC 1-A

		2021-2030	2031-2040	2041-2050
Milestone	TPS	350,000	450,000	500,000
	Node	10,000	100,000	300,000
Research Task		Ensuring scalability for the use of blockchain in fisheries across the country.	Ensuring scalability for the use of blockchain in the marine food industry across the country	Ensuring scalability for the use of blockchain in the marine industry across the country
Effect		Fishery and fishery-related goods (data, information, usage rights, and value) are safely managed in a decentralized manner and can be promptly traded.	Marine food and goods related to this industry are safely distributed and managed, and can be traded quickly.	All resources produced by the marine industry and goods related to this industry will be safely managed in a decentralized manner and can be traded promptly.

*TPS: Transaction per second (throughput per second)

RESEARCH TOPIC 1-B-1

	2021-2030	2031-2040	2041-2050
Milestone	Online trading of fishery products and goods (data and usage rights).	Online trading of marine food products and goods.	Online trading of products and goods related to the ocean.
Research Task	Designing a market for secure, automated online trading of goods originating from fisheries.	Expanding the scope of online automated trading to include all goods related to the marine food industry.	Expanding the scope of online automated trading to all goods of marine origin
Effect	Creation of a market for automatic trading of goods originating from fisheries under certain conditions.	Automated trading market for ocean-derived goods expands	A market for automated trading of all ocean-derived goods becomes popular.

RESEARCH TOPIC 1-B-2

	2021-2030	2031-2040	2041-2050
Milestone	Development of a decentralized infrastructure to coordinate and control the production and distribution of fisheries.	Development of a decentralized infrastructure to coordinate and control the production and distribution in the marine food industry.	Development of a decentralized infrastructure to coordinate and control the production and distribution throughout the marine industry.
Research Task	Development of smart contract technology that automatically adjusts and controls production and distribution based on supply and demand forecasts for fisheries	Extend the basis for decentralized coordination and control to the marine food industry.	Extend the basis for decentralized coordination and control to all marine industries.
Effect	Sustainable and optimal use of energy and catch required in the fisheries supply chain	Sustainable and optimal use of energy and food required in the supply chain of the marine food industry	Sustainable and optimal use of energy and ocean resources required in the supply chain of the marine industry

b. Ocean visualization

	2021-2030	2031-2040	2041-2050
Milestone	Understanding and prediction of natural ecosystems will be achieved for marine living resources.	Understanding and predicting the parts of the ocean that will be used by humans. Visualization of ocean resources related to energy and zoning will also be achieved.	Full visualization of the ocean and ocean use in all ocean areas will be possible.
Research Task	Develop technology to integrate and model a wide variety of databases using AI technology, focusing on marine living resources.	The challenge of integrated modeling of data that includes more than just marine living resources. We will package integrated modeling technologies to make analysis easier for those who do not have deep expertise.	Develop a model that integrates physical environment and biological resource trends for the entire ocean area.
Effect	This will provide the basic technology to properly handle the large amount of data of varying quality and resolution expected in the future, and to extract meaningful information. Through the understanding of the process, the accuracy of predicting medium- and short-term trends in living marine resources will be improved, leading to the optimization of decision-making.	Model the parts of the ocean that are used by humans, leading to improved understanding and prediction accuracy. In addition, the results of forecasting medium- and short-term trends in overall marine resources will lead to optimized decision-making.	A wealth of "live" information will be available that will greatly expand the way we look at the ocean and how we use it.

c. Optimizing the use of the ocean

RESEARCH TOPIC 3-A

	2021-2030	2031-2040	2041-2050
Milestone	Develop and operationalize a Minimum Viable Product (MVP) decision support system for fishermen in a specific region. Improvements will be made based on the opinions of the users. Based on the results of the MVP, the development of an information system for actual operation will begin.	Based on the results of a particular region, expand the decision support system nationwide. An additional functional aspect will be the ability to optimize behavior for resource use other than fishing.	Technology is being developed that will allow anyone, anytime, anywhere, to efficiently utilize marine resources if they decide they want to do so.
Research task	Formulation of a decision-making system that inputs information on fishing conditions, sea conditions, demand, and vessel performance, and outputs the actions to be taken. This includes modeling, such as identification of demand curves and cost curves, and optimization based on the results of the model.	For ocean use in general, we will also develop methods for modeling and optimization using the results of the models.	We will develop techniques to formulate the nature of individual decision-making and to enable the evaluation of social decision-making processes as an accumulation of such decision-making.

RESEARCH TOPIC 3-B, 3-C

	2021-2030	2031-2040	2041-2050
Milestone	For specific or small-scale issues that are relatively easy to formulate (e.g., management of fishery resources), a unified protocol for evaluating socially agreeable measures based on scientific evidence according to values and objectives will be completed and put into operation. For ambiguous and large-scale issues that are difficult to formulate (e.g., treatment of common goods, superiority or inferiority of centralized and decentralized societies, design of ideal social systems), prototype technologies for implementing policy evaluation will be completed in the methods of mathematical modeling and computer simulation.	For issues that are easy to formulate for comprehensive marine and natural resource use in general, the policy evaluation protocols obtained by 2030 will be applied to the actual issues in question and their solutions will be sought. Even for issues that are difficult to formulate, MVPs will be created and verified.	Each person will be able to choose and comment on the social system he or she desires after understanding and being convinced of the challenges and benefits of the social system. Since the effects of social action can be scientifically quantified, visualized, and returned, social action can be continuously improved.
Research task	Development of stochastic simulation techniques that mimic the interactions among fishery resources, fisheries, and social systems. Development of a software MVP to share results widely and support evidence-based social decision making.	Development of technologies to represent and evaluate issues that are difficult to formulate using agent-based simulations and other methods.	Design a process to improve the social system as a country based on the results evaluated in the simulation.

EFFECT (COMMON TO 3-A, B, AND C)

Effect	Personal efficiency in resource use will be achieved. Correspondence between values and behaviors with regard to social change will become apparent.	The efficiency of resource use will spread throughout the country. Evidence-based social decision-making and policy evaluation will be widely used.	Efficient social use of resources will be achieved while individuals act independently. It will be possible to dynamically redesign - reevaluate - and apply social systems to society as needed.

3. International cooperation

Although the focus of the goal until 2050 is on Japan, the motivation for proposing this goal is the study of international collaboration on the oceans and the resulting international policy development.

High Level Panel for A Sustainable Economy", an international intergovernmental meeting in which Japan is actively participating to achieve the Sustainable Development Goals

(SDGs) from the ocean (Panel for a Sustainable Ocean Economy) is the only international ocean policy organization capable of strengthening the relationship between humankind and the oceans, collaborating with diverse stakeholders, and using cutting-edge knowledge to achieve a sustainable ocean economy. Last December, the International Ocean Panel developed a prioritized action agenda for the transition to a sustainable ocean economy. From here and now, we will initiate, amplify and accelerate international action based on the Action Agenda.

Last December, the International Ocean Panel's Action Agenda cited as one of its scientific bases "The Future of Food from the Sea," a set of recommendations for the next generation of ocean policy based on research by experts, including a member of the "New Ocean Nation, Japan" team, on the potential for food supply and economic development from the ocean (Costello et al. 2020). The results of this study, which were also published as an academic research paper in Nature, demonstrated through science that a sustainable global food supply from the ocean and its economic activities could solve the world's hunger and poverty problems in 2050, and articulated policies to achieve this. Science has shown the way to build a world out of oceans, and countries have agreed to follow that path together. However, there is still no concrete action on food supply and economic development from the ocean in 2050.

To achieve this Moonshot Goal by 2050, continuous technological innovation is necessary, and there are difficulties in managing the R&D system only with the moonshot R&D system, which is scheduled to end in 2030. In addition, even if key technological innovations are funded by public research funds, they will not lead to continuous innovation without the development of applications based on market principles.

4. Interdisciplinary cooperation

Since the Moonshot Goal is to create a new nation with a new type of social capital, there is a wide range of cooperation and coordination required. Here, we will focus on the collaboration between industry, academia, and government over the ocean, which is often referred to as the bottleneck in the expansion of ocean utilization.

Looking over the history of marine research and the marine industry, it is unfortunately difficult to say that the results of university research have supported the development of the industry. Japan's world-renowned fisheries industry is no exception, and there are many who point out that research has not been translated into concrete measures in the field (https://www.jstage.jst.go.jp/article/suisan/87/2/87_WA2765/_article/-char/ja/).

When we learn from history, we realize that what is needed to make ocean utilization a wave of development is for industry, government and academia to work together on Proof of Concept (PoC) of ideas. Proof of concept refers to the verification of feasibility and practicality of an idea or new concept by realizing it in society on a minimal scale.

Unlike demonstration projects where a huge technology is floated in the ocean and tested independently, PoC is characterized by bringing the smallest technology or mechanism that embodies an idea into the real world. and current laws. PoC is truly a place of collaboration between industry, government, and academia. And if we are dealing with a public good such as the ocean, PoC is not possible without industry-government-academia collaboration.

Until now, PoC has not been a conscious effort in the world of marine research and ocean utilization technologies. It is possible that some of these experiments were not bad ideas, but simply lacked the PoC approach and ended up being half-hearted and not implemented in society.

Therefore, in this MS Goal, we will proceed with a strong focus on PoC. To give an example, in the wealth accumulation of the ocean, we will first focus on the fishing industry, starting with the fishing boats that gather at a single fishing port. The data generated during the entire process of a fish caught by a single boat leaving port on a certain morning, until it reaches the hands of consumers, is collected as much as possible and managed and traded using a blockchain. This will involve fishing boat owners, fishing rights owners, fishermen, fishermen's cooperatives, fish processing companies, transportation companies, retail companies, certification organizations, marketing companies, consumers, lawyers, local governments, relevant ministries, fisheries researchers, and blockchain engineers. We will engage in such industry-government-academia collaboration that their judgments will be consolidated into judgments of the feasibility of the concepts and ideas on which this Moonshot Goal is built.

5. ELSI (Ethical, Legal, Social Issues)

The goal of the MS is to optimize the use of the ocean as marine natural capital by 2050 through the development of technology and its social implementation, and by stimulating economic motivation through the Ocean Cycle, which is Ocean social infrastructure based on new blockchain technology. Society and people will be invited by the new technology to establish a new relationship with the ocean as a shared regional asset and create new value.

The Sixth Science and Technology Innovation Basic Plan states that in order to solve social issues and create new value through technological innovation, it is essential to address ethical, legal, and social issues (ELSI) from the initial stage of research and development by involving stakeholders and others and using "comprehensive knowledge. (The Sixth Science and Technology Innovation Basic Plan). When a new technology is introduced into society, there are many cases in which it cannot be dealt with by the existing social system or by the existing system. As a result, ELSIs may occur and problems may arise that prevent the new technology from being accepted by society and implemented in society. Therefore, it is necessary to understand the potential risks associated with the introduction of new science in advance, establish norms, and build social consensus (Higo et al. 2021).

The major ELSI issue in this Moonshot Goal is to promote research and development and social implementation while discovering and predicting ethical, legal, and social issues from the long-term perspective of 2050 in the current society of 2021. The Satoumi Community 5.0, as the main entity for the rights and management of regional common goods, envisions a diverse system of rights for marine use that cannot be addressed by the existing legal system, while starting from Japan's unique joint management. In particular, the Fishery Law provides for fishery rights, "the right to engage exclusively in a specific type of fishing in a certain water surface for a certain period of time. It is necessary to consider the appropriate revision of the system in line with the wealth accumulation of the ocean.

In addition, for the commercialization of data, it is necessary to establish laws and regulations regarding the exclusive access, ownership, and transfer of rights to digital data that has the potential for reproduction (mapping). In addition, the establishment of a data market will require compliance with the Personal Information Protection Law for data handling and the Financial Instruments and Exchange Law and other related laws for market operation. With regard to market operators, a system in which the government certifies those who meet certain requirements and publicizes them to ensure reliability is envisioned. However, aiming for a decentralized and democratic system, a method in which operation is promoted through the voluntary efforts of the parties concerned and in which the parties concerned formulate rules that match the actual situation (Mano 2021) should also be considered.

In this research goal, which is a research and development aiming at the year 2050, we will start from the obvious legal issues from the Proof of Concept in the early stage of research and development, and proactively discover and predict ethical issues through the trial of social implementation, which will enable us to uncover and respond to potential social issues. For this purpose, the only solution is to add applied ethicists, legal scholars, and practitioners to the research team and promote ELSI as a clear research topic. Although not included in the members of this proposal, the goal review team has already obtained the consent of the international experienced applied ethicists, legal scholars and practitioners to participate in the practical ELSI when it transitions to the research and development team. While the research, development, and technology of this goal is aimed at transforming the world's oceans beyond 2050, it is clearly designed for the geography, unique values, and people of Japan. Therefore, ensuring the inclusion of ELSI in research and development has the potential to make a significant contribution to the research and development of practical ELSI methods in publicly funded research that will ensure the bridge between science and technology and social implementation.

IV. Conclusion

Our MS goal is “Toward establishing Japan as a New Ocean Nation by 2050-- Create ocean infrastructure to drive the cycle of wealth accumulation, visualization, and optimal utilization of the oceans”.

In the development of our MS goal, we have reached two major turning points.

The first is that we are once again confronted with the uncertainty of the oceans. Our decade since the Great East Japan Earthquake in 2011 was with oceans. The oceans are the future of this country - this is an unquestioned conviction for us.

On the other hand, while there are countless innovative marine-related technologies, only a limited number of them have been implemented in society. There is a great deal of public-funded ocean research and technology development in Japan, but none of it has been widely adopted by the community. This led us to conclude that technology alone is not a right solution toward Japan turning into an Ocean Nation.

What we have found through this MS research is the uncertainty of the oceans, which we have been trying to overcome for a decade since 2011. Visualisation of the oceans could help overcome this uncertainty and create an economic incentive for the spread of ocean-related technologies in society.

Secondly, we have discovered the possibility of advancing the visualization of the oceans through the fusion of physical and cyber space.

Predecessors have been trying to overcome the uncertainty of the oceans through fisheries in vain due to an overwhelming lack of data needed for 'ocean visualization.'

To increase the data, we stimulate the economic motive to trade ocean data. The autonomous decentralized blockchain protocol, which our members are developing and aiming to open source, has a potential to become the key technology to make the trading market of ocean data a reality while the protocol merges the physical and cyber space . As the data market increases data supplies and demands, the ocean will be more visualized by the increased data. The “ocean visualization” will contribute to “ocean materialization”. In other words, the feasibility of the ocean social capital "Ocean Cycle" will increase.

The ocean social capital can extend Japan's unique co-management of regional oceans into cyberspace, which will lead to the development of the Satoumi Community 5.0.

The establishment of the new “Ocean Nation, Japan” is our goal on the path started at the Meiji period when Japan opened its doors to the outside world. It is worth noting that the New Ocean Nation will not exist on the basis of national power secured by wealth or global hegemony. Rather, it will depend on collective measures to create a social ocean capital "Ocean Cycle".

Asan island nation, Japanhas no choice but to face the natural disasters caused by the oceans and difficulties of economic development. Our history has proved that Japan could accept them with flexibility and development. It is the destiny of this country to keep overcoming these difficulties with the oceans.

The "New Ocean Nation, Japan" of 2050, the moon we look up to, is undoubtedly shining with our destiny to overcome these difficulties. Dim glow on the path to the moon ahead, now the first step has been taken.

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