Innovation Promoted by Meta-Engineering
- Mining-Exploring-Converging-Implementing Process

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ABSTRACT

The authors propose a new creative concept of "meta-engineering" as a dynamic engineering approach that is effective for breakthrough innovation.

A science and technology driven country is expected to play a leading role in addressing increasingly more diversified global issues and in solving them with maintaining harmony of sustainable growth of human society and preservation of environment in recent years. A key for performing such a role lies in innovation by continual orchestration of global issues, science and technology, and new social value.

Addressing merely emerging issues with science and technology is insufficient for realizing breakthrough innovation. The proposal maintains that the spiral process is a key driving force for innovation and solution of challenges that future societies are faced with. The processes include "mining invisible and potential/latent issues from bird's eye point of view (M)", "exploring and strengthening necessary science and technologies (E)", "converging these science and technologies to generate solutions (C) " and "implementing them for creating social value (I)". These processes are represented as MECI process.

"Meta-engineering" that the authors propose is different from the engineering approach of today that focuses only on converging of technologies. "Meta-engineering" is to promote radical innovation going down to the root of a superficial problem.

Keywords: Innovation, Science and technology, Converging technology, Meta-engineering, Issues.

1. INTRODUCTION

The authors are working as members of the Engineering Academy of Japan (EAJ). EAJ has the Committee on Technology Policy that proposes effective policy of science and technology that are necessary from the standpoint of engineering for society.

Globally cloud computing, smart grid, and iPhone/iPad are coming out as innovation. On the other hand, not so many innovations are coming out from Japan while Japan is said to be extremely good at engineering, capable of making excellent products, and has competent craftsmen. This is the start point of the investigation.

Engineering has many definitions and it is often defined "to design under constraints [1]" in National Academy of Engineering in the US. or "to provide an optimal solution within a limited given condition." The authors question whether these definitions are sufficient. Totally different answers may be obtained that may lead to innovation, by removing the constraints, instead of by narrowing down. In studying innovation, the authors first took notice of "converging technology," which is an idea developed in the US [2] and the EU[3]. If this idea fits well in Japan, just need to be developed into a Japanese-style converging technology. After analyzing these activities the authors reached a conclusion that meta-engineering is the key factor for innovation.

2. CONVERGING TECHNOLOGIES IN EUROPE AND US

Converging technologies (CTs) start with identifying what the future challenges will be and exploring what sciences and technologies will be needed for them. In the final proposal of CTs, the four fields of NBIC – nanotechnology, biotechnology, informatics technology, and cognitive science – are identified as the core technologies [4]. It also says that any single field of them is not enough to address global issues and that converging multiple fields are necessary. "Converge" means "to bring together." While the four fields of NBIC are originally independent, they should be converged keeping the original fields. Some fields may merge into a new field if a new field emerges, but the respective original fields must remain as well.

3. CONVERGING TECHNOLOGIES IN JAPAN

In the US where innovation continues, the people are superior in mining potential issues. They find issues to address solutions, and then make all efforts for the solutions. Japanese are good at finding a solution for a given issue under limited conditions, but are rather weak with open questions with no limits nor conditions. Innovation is not realized unless approaching the unseen issues and seeks solutions. It is necessary to think what is behind the visible issue, what the real issues are, and what the hidden issues are.

When a Japanese company does business, it tends to think, "We are capable of doing this. How could we make this into business?" In US Company, however, it has a clear vision "we want to do this kind of business." A project starts in a top-down style, where the top people think what they have, what they don't have, and what they should do. In Japan, the bottom-up style is very strong, where the technology that the company possesses is molded into a new product.

Two typical Japanese products are as examples. First one is an air conditioner. It is highly efficient. It uses intelligent inverters and heat pumps, and utilizes very fine technology. Secondary the hybrid vehicles combine the gasoline internal combustion engine and the battery motor in a sophisticated manner. Two of these are both very excellent in a manner that these solve the visible problems under the given constraints. Since the Japanese are capable of such skills, they try to solve problems in that manner.

4. META-ENGINEERING

The authors decided to name the effort of mining potential issues and solving them by removing the limitations as "meta-engineering." (Fig.1) The definition of Meta-Engineering is as follows:
First we find the hidden and not apparent issues in our society. Then we look for the appropriate science and technologies to solve this issue. In many cases it is difficult to solve the issue by single science and technology and we need to converge several science and technologies. Finally we implement this solution to the real world and get new value to the society.
Several references show the term meta-engineering has been used in some areas [5], [6]. The authors selected this term for this proposal. After considering other candidate names such as "holonic engineering," "comprehensive engineering," "ecological engineering," "transformative engineering," or "Japanese converging technology," etc.. The authors, however, determined as meta-engineering since this name produces an image of metaphysical engineering as a level above current engineering. Meta-engineering places "why" question at the beginning. For instance "why is innovation is necessary in energy field?" One of the answers will be "to keep the global environment and natural resources for our next generation."

Always keeping the above "why" in mind, meta-engineering is to circulate the four processes into a spiral. It begins with mining process to find an invisible and potential or buried issue (M), and then exploring necessary science and technology to solve it (E). If the issue cannot be solved by existing science and technology, some technologies are converged (C). Finally, the solution to the issue is implemented (I). These processes are represented as "MECI." Another new issue emerges in this process. The image of the four processes turning round and round is important.

One of the reasons of returning to the process of mining a new issue is that innovation is meaningless unless it continues. And so the four processes repeat cyclically.

In that sense, it is a spiral rather than a cyclical feedback. It means that, the world may change by introducing new things, but some other potential issue arises because of that new introduction.

This MECI process is cultivated in meta-engineering field or "Ba" in Japanese.

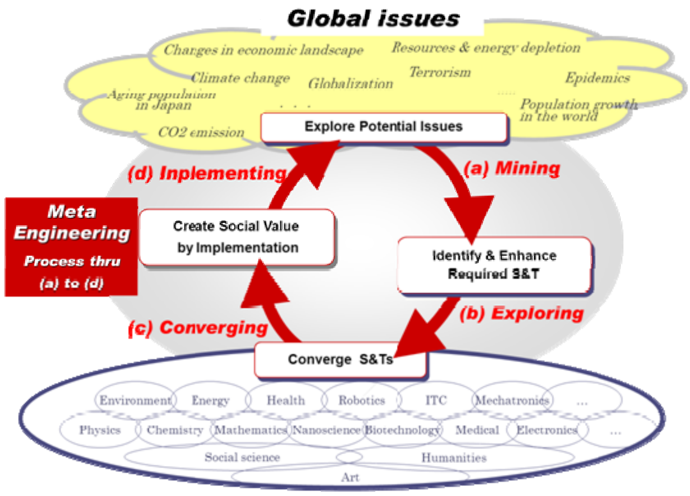

Fig. 1 Meta-Engineering

5. IMPORTANCE OF 'WHY' PROCESS

The most difficult part is mining potential issues. The authors have no specific plan at the moment, but marketing shows some hint.

A salesperson visits a client, and the client says, "I want to drink some juice." (Fig.2) In a Japanese company, the salesperson will purchase a high technology juicer and some fresh fruits, make juice, and take it to the client. The client will be 100% satisfied and may buy the glass of juice for 10 dollars. Though the actual cost maybe 9 dollars to buy the juicer and the fresh fruits. Selling the glass of juice for 10 dollars generates 1-dollar profit. In a Japanese company, this is highly evaluated because the customer satisfaction is 100%.

On the other hand a US company looks at the root of the issue. If the client says, "I want some juice," the salesperson will ask, "Why do you want juice?" (Fig.3) When the client answers, "Because I'm thirsty," the salesperson will sell water. This will solve the client's thirst. Another client may say, "I want some cola." He may be just thirsty. Then, the salesperson will sell a glass of water for 1 dollar to 10 thirsty clients. If he sells water for 1 dollar a glass, the sales will be 10 dollars. Assuming the total cost of 10 glasses of water is 5 dollars, the profit is 5 dollars.

In this example a Japanese salesperson misses the process to identify "what is really necessary." The
authors consider this process is important and Japanese should train themselves to acquire this point of view. The Japanese are keen on "how" and "how- to." But they need to go beyond into "what is really important" and "why" so that they would mine invisible potential issues. In the example "what" is to know that a client wants juice, "how" is what kind of juice to sell, and "why" is that the client is thirsty.

In conventional engineering, "what" is given as a problem to be solved, and an engineer figures out "how" to make something. It is suggested that an engineer go down to "what" and "why."

Through the discussions in EAJ the authors noticed two major points. One is education: How to help people realize the importance of "why" process. The other is further research of meta-engineering itself. These are the current tasks that the authors propel.

As to education, debating is a common and effective measure in the US. In the course of debating, the settings and perspectives will change. Through debate people will learn switching perspectives.

There was a symposium on privacy and security in the information society, organized by the engineering academies of Japan and the UK. Japan discussed about how pattern recognition could be performed by video cameras and at what angles the cameras should be set. The UK started a discussion on the institutional approach of security conservation, of how to privacy while maintaining national security.

Japanese engineers are accustomed to saying nothing about the system. They focus on technological aspects because they consider that it is what they are expected to do.

Switching perspectives are important for engineers who tend to get fixed a perspective if they stay in one place too long.

US company respects carrier mobility. Someone in sales division may go to marketing division, or M&A one, which the authors regard business development, or do project management. People can experience different types of work to enhance their own expertise. If one stays in a position for 18 months, he/she earns the right to move to another section in some US company. There exist incentives to encourage mobility.

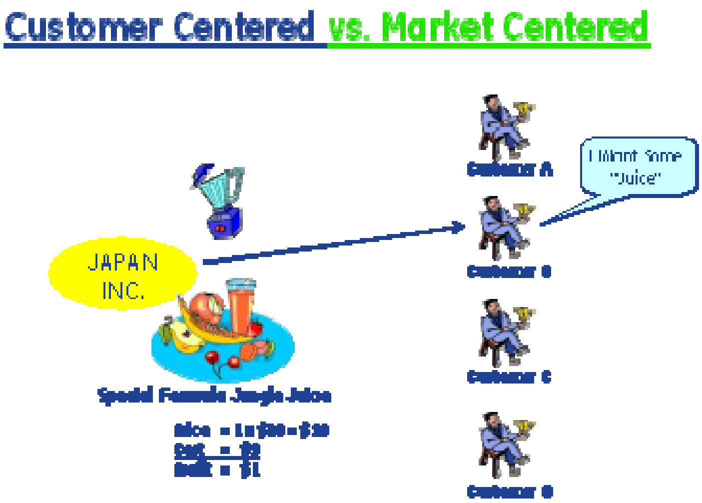

Fig. 2 Customer Centered Approach

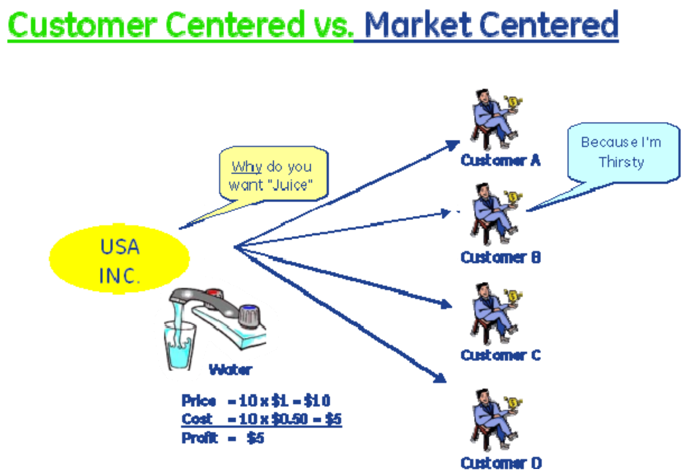

Fig. 3 Market Centered Approach

6. MANAGEMENT OF TEHNOLOGY AND META-ENGINEERING

There is a close relationship between management of technology (MOT) and meta-engineering. Management of manufacturing technology, as an example, shows the similarity between MOT and meta-engineering. Here the important thing is not only manufacturing process but also the kinds of product to market, develop, manufacture and sell. Namely the multiplication of "what" and "how" must be considered. In short MOT is the multiplication of "technology" and "management" under the uninterrupted dialogue with market place. Even if you have a good technology, it will be useless without good management. And good management is meaningless without a good technology. Balancing of multiplication of technology and management is important. Meta-engineering can play a significant role here.

There was a book written by Lester and Piore, "Innovation: The Missing Dimension [7]." It says, "Innovation will take place interpretively rather than analytically." The authors felt that this perspective was new to Japan. Therefore it is important to expand engineering to interpretation rather than to analysis only. People with engineering expertise have the knowledge of analysis. So if they enter the interpretive process they may be able to attain meta-engineering.

This meta-engineering is practically realized in the innovation of smart grid in energy area, cloud computing in information area, and will be applied to create innovation in mobility of human beings transportation in future.

7. METHODOLOGY AND APPLIED EXAMPLES

The outline of the methodology of the meta-engineering is shown in Fig. 4.

When one applies meta-engineering to an issue to be studied, the first step to be followed is to state "Why it is the issue to be studied" based on the field on which "What is the issue to be studied." Then it is necessary to dig the "What." The process will become the one shown in Fig. 5.

What can become "why"? Anything will be allowable only if engineering will be workable and is ethically acceptable for the proposition. It is unsuitable if the motion is based on the greed to get money by cheating socially vulnerable people, such as a retired handicapped person or a young child even if it will be easily attained by applying modern ICT technologies.

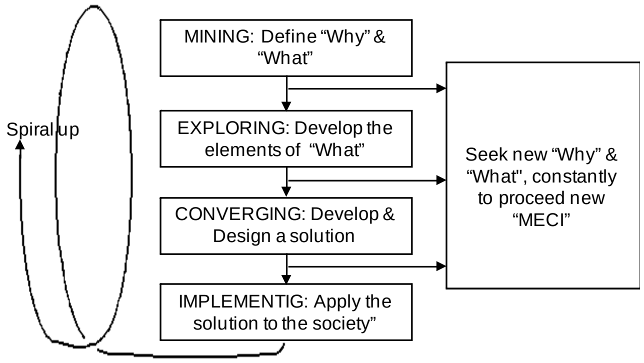

Fig. 4. Outline of the methodology

Let us show an example. Suppose the basic field be an energy problem. Why is the energy problem to be studied? Because it is the science and technology heavily related issue and it has to be overcome for the survival of human beings and for the sustainability of the earth. These are the definitions of "Why."

When one applies meta-engineering to an issue to be studied, the first step to be followed is to state "Why it is the issue to be studied" based on the field on which "What is the issue to be studied." Then digging the "What." The process will become the one shown in Fig. 5.

As far as the proportion of the electric energy continuously increasing to occupy major part in the total energy consumption, electric energy system should be innovated dramatically. More concrete expression of the subject is described as follows. The generation and consumption of electric energy are so rapidly changing that the grid system to connect these should be innovated dramatically. The innovation could be one of the vital solutions of the previously stated "What." It is seldom understood by the general public why the grid plays very important role in the electric power system to use electric energy effectively.

The emerging issue about the power grid is "smart grid." Therefore, the next "What" will be as follows. "Up to today, the efficiency and reliability of the electric power system has been raised by enlarging its scale. Without killing the strong point of the large scale power network, and with promoting electric power consumer be also a small scale power producer, we would have the power system of next generation. To develop the innovative way to go together of large and small is the key issue." This is the meta-engineering "What" statement on the smart grid and above description is the "Mining" stage.

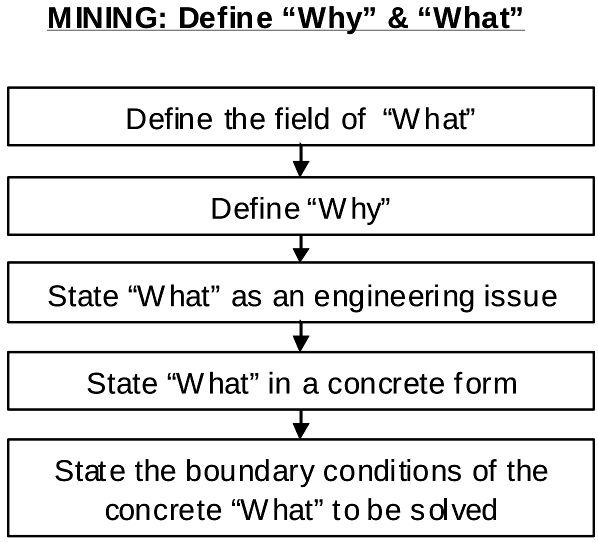

Fig. 5. Mining Stage

Next is "Exploring." The process shown in Fig. 6 will be followed.

It is necessary to develop the concrete parts, another word, constituents which form "What" of the smart grid. There are many; for instance, solar and wind power generation equipment, electric energy storage including battery for automobile, various electrical household appliances ,and ICT equipment and software to connect these parts. Some of these are in a so called "Green House," others are in the grid. Various types of infrastructures which support metropolitan and urban life would be taken into account. It is sometimes effective to defuse the analysis intentionally ,so that interesting new issues may be found.

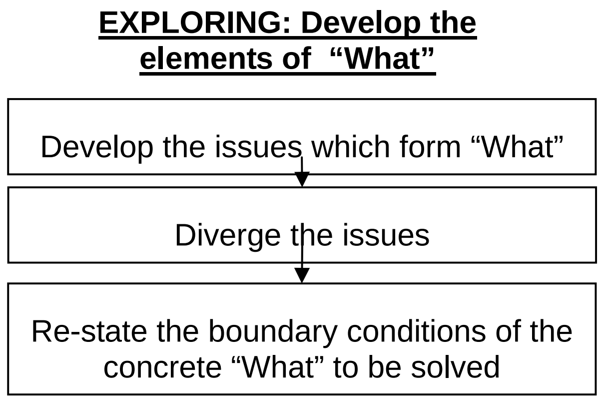

Fig. 6. Exploring stage

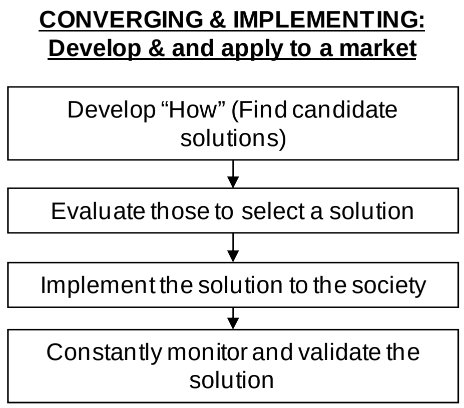

Fig. 7. Converging and Implementing stages

These are all electricity related parts. Here, the distribution and consumption of electricity is connectively considered. Electric current form and voltage height are the issues. Which are the more convenient form, alternative or direct current for a specific purpose? How high voltage is effective for distribution and consumption. The electrical current from solar power panel is at first dc. Electricity from wind power is at first unstable ac. TV and personal computer use very low dc voltage to drive their electronic circuits. Air conditioner and refrigerator receive 50/60Hz ac, then change its frequency, another words, change received 50/60Hz ac to dc then dc to ac of adequate frequency.

Electric energy storage is another important issue. Until today, although pumping up hydro power station has worked effectively as energy storage, and fuel cell storage has continuously developed, the amount of storage has still been insufficient form the smoothed electric load curve point of view. The large number of very small distributed electric power storage, that is an automobile battery, is dramatically changing the situation by being connected to power grid. Together with solar cell, electricity is becoming consumed at the very close place where it is generated. This type of generation-consumption ratio will increase heavily. Then is everything distributed?
The authors think "No." The development of technology and business model by which many types of concentrated and distributed power generation are smartly connected, monitored and controlled would be the winner of the coming electric energy field.

Many other issues are to be considered in this field, such as compatibility, standardization, construction, maintenance, disposal, ownership of equipment and so on. Standardization, maintenance and disposal are especially important to the distributed equipment. Ownership innovation might ease the problem.

It is then important to clarify the boundary condition of these issues, another word to specify the conditions so that each problem would be solvable, by exploring these issues without sticking in a single science and engineering domain. After that, the process to seek candidate solutions by combining the knowledge of related fields or by deepen a specific field is proceeded. Then the most adapted solution is selected (sometime plural solutions are selected), developed, designed and implemented (Fig. 7).

At the final stage, the business incentives are quite important. Not only business model but also social systems such as taxation and regulation (de-regulation) must be innovated.

8. CONCLUSIONS

Meta-engineering can be applied globally for promoting innovation creation. As Japan boasts manufacturing, it should maximize the accumulated experiences as its strength. The MECI process shall be much more activated to create innovation. In order to promote this concept one important activity is education on meta-engineering in engineering course. And the other is to cultivate "Ba" or meta-engineering field on which the MECI process is smoothly carried out.
For further deepening and perfection of "meta-engineering," more accelerated investigation and specific demonstration and implementation in parallel are indispensable. Such actions require well-coordinated and intense academia-industry-government collaborations with close interactions with the general public, under the national and international science, technology and innovation policies execution.
The authors emphatically propose to put a high priority on the development of "meta-engineering" as a new approach for innovation and sustainability for generations to come.

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