WORKING PAPER

A STUDY ON THE INNOVATION PROCESS
Governance and Japanese Culture

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Presented at Joint Workshop of IIASA and JISR on the Decision Support Systems, IIASA, August 3-5, 1987, Laxenburg, Austria

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Foreword

Research in the field of Methodology of Decision Analysis and Decision Support Systems is one of the topics investigated during several years within the System and Decision Sciences Program. Beside theoretical and methodological research, applications are considered as a very important component of this research. Developing methodologies and computer systems requires practical verification of these concepts as well as the learning of decision making styles and practices from organizations implementing up-to-date management techniques. Application and experimentation is the only possible approach for the validation of new concepts developed by researchers and feedback from practice is one possible way for generation of new ideas.

Recognizing the importance of the above mentioned feedback, the System and Decision Sciences Program organized joint Seminar Days with the Japan Institute for Systems Research with participation of managers from leading companies of Japan industry. During this seminar they presented experience on implementing new management and decision making technologies in their organizations. The given paper presents several aspects of management in the context of introducing innovative technologies at Mitsubishi Electric Corporation.

Alexander Kurzhanski
Chairman
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Author

Jun-ichi Baba was born in Osaka, Japan in 1926. He received the B.E., the M.E., and Ph.D. degrees from Tokyo University in 1947, 1949, and in 1954 respectively.

He joined Mitsubishi Electric Corporation in 1952. From 1977 to 1981 he was General Manager of Central Research Laboratories. From 1981 to 1985 he was Director and General Manager of Head Quarters Engineering and Manufacturing. Since 1985 he has been a Board Adviser. Since 1987 he has been a lecturer at the Department of Business Administration of Kobe University. He is a leader and a member of the committees of government and electronics business association.

Abstract

Innovation is a key for the growth and the evolution of a corporation. We are seeking what is essential for the innovation and what is newly required for the corporate management. We will show our experience of laser diode development, based on which we propose the four stages of innovation; jumping from the ordinary framework, recurring to it, systemization and civilization. This innovation process is also explained from the view point of the sense of human beings; aesthetic sense, which is usually thought as for the arts.

Another important point is the concept of governance which is more philosophical than the concept of management. It is shown that the role of corporate management is explained clearly by the concept of governance as well as that of management.

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1. DEVELOPMENT OF LASER DIODE FROM RESEARCH THROUGH TO PRODUCTION BASED ON INTERNAL CORPORATE VENTURING

1.1. The Beginning of Research into Laser Diodes

The concept of a laser diode (PN junction and axial resonance structure) was first announced by Professor J. Nishizawa of Tohoku University, Japan in 1957. However, little attention was paid to it then.

In 1962, GE, IBM, and MIT in the United States announced the pulsating motion of GaAs PN-junction laser diode in liquid nitrogen, from which the laser diode began to attract public attention. However, the discovery of pulsing motion was made in the limited sphere of liquid nitrogen, leaving a large gap to be filled for it to be practically useful. In 1963, Kroemer of the United States proposed the efficiency of current injection into semiconductor lasers. In 1970, Hayashi, now engaged in joint research of optics in the United States, and others attained an oscillation at room temperature with a laser diode having a double hetero-junction structure. This caused both researchers and engineers to push for the development of a practically useful laser diode.

1.2. Problems to be Solved for Practical Use

The primary objectives of developmental work were to remove crystal defects in subrates and extend life-time by reducing the structural-process current, and to improve the lasing mode, pattern, and spectrum of laser light by using innovative device structures and manufacturing processes.

1.3. The Beginning of Laser Diode Development at Mitsubishi

Mitsubishi Electric started developing a GaAs laser in 1963. In 1967, through the epitaxial growth of an AlGaAs layer on a GaAs substrate, the company produced the world's first prototype visible laser in a wavelenght of 0.78 μm using an AlGaAs PN-junction laser. The development of this prototype laser was introduced at an international conference in 1968.

Also in 1968, Mitsubishi Electric produced a prototype single-hetero LD and became the first company in the world to attain oscillation in LN2. The wavelength of 0.78 μm is now the standard for short wavelength LDs.

1.4. First Phase of Laser Diode Work at Mitsubishi

In 1974, the company devised its unique TJS structure and succeeded in attaining steady state in both transverse and axial modes, and at the same time made efforts to find what factors related to the life of laser diodes. In 1975, this study discovered that primary life factor was inclusion of oxygen. With the development of a manufacturing process to remove the oxygen to 0.03 ppm, the company attained a life-time of 10,000 hours, then the longest in the world, while reducing the current requirement to just 20 mA. These accomplishments led to commercial production of the laser in 1978.

In 1976-1978, the leader of the development group went abroad to announce the results of development at an international conference, while there he attempted to cultivate the market without waiting to see how the Japanese market would respond to the development. He distributed samples to users in the United States at large and gathered information from their evaluations and by consulting with them; this market research was then reflected in device development and production. His achievement was acknowledged by U.S. magazine, Laser Focus, as follows: "The introduction into the U.S. market in the latter half of 1970 of a low-cost, single mode laser diode featuring superior performance and reliability, was a major gave impact on the optical disc laser printer and fiber optic communication markets and played a part in guiding the course of development of that market".

Further, in 1981 he won a prize from the Japanese communication society. This spell of achievement by Mitsubishi Electric was a feat both in Japan and in the world in that its impact was felt in the development of laser technology and in the laser market.

1.5. Second Phase of Laser Diode Work at Mitsubishi

After 100,000 hours of laser-diode service lie in local-area TV transmission systems (1977) and in tests made to NTT standards (1984), an approach was made to use laser diode in the Japanese communication market. However, the greatest success for the laser diode from business point of view was its use in digital audio disc (DAD) and compact disc (CD) players. In 1985, production of the laser diodes reached 500,000 units per month, making the company one of the world's largest producers of this type of product. The success, however, was by no means achieved by the development of laser chips alone.

Mass-production facilities for new devices, especially those for transducers in which input and output values are dissimilar in physical quantities, are not normally available on the market unlike those for IC production. Often device manufacturing facilities are especially true for those who pioneer high technology. Unless this barrier is overcome, and highly efficient production is ensured, no one can expect success in this field.

Since laser diodes require the optical parts to be assembled to extremely close tolerances and their package structure is quite different from that of existing semiconductor ICs, development work needed to begin from basics and the development period was prolonged.

Four years of cooperative efforts within an intra-company development division resulted in the development of a series of fully-automatic assembly and inspection lines in 1981. This success was unchallenged by any other company.

Since 1975, close collaboration with the company's applications research and development division has clarified the properties required for lasers used in compact disc (CD) laser pickup systems; those findings were incorporated into the development of their own laser. This success was followed by the establishment of a division in the company in charge of producing CD pickup systems using laser diodes. As the largest supplier of laser diodes in Japan, the company played a leading part in creating a market for the product.

1.6. Reasons behind the Success of Laser Diode Work at Mitsubishi

Laser chip development, from research to production and to distribution, was accompanied by several epoch-making innovations in the development and production stages. Among these, the following are notable for contributing to success in the work on laser diodes:

1) an approach to customers and information gathering was made from the beginning;
2) an innovative automatic assembly and testing line was developed and manufactured by the company at an early stage;
3) powerful cooperation was obtained from within the company through participation by applications research and development division and applications business enterprising division; and
4) technology transfer from research division to manufacturing division, as well as transfer of the key personnel, was smoothly performed.

1.7. Effects of Laser Diode Technology on Other Division of Mitsubishi

A great spin-off from the development of the laser diode and one which influenced other divisions of the company was the development of GaAs solar cell. It came about from the expansion in range and scale of applications of hetero liquid phase epitaxial technology which derived directly from laser diode development. The developed solar cell attained the world's highest conversion efficiency of 21%. Those cells were used in space exploration and earned worldwide acclaim.

A decision has already been made to use these solar cells in CS-3 satellite to be launched in 1987. Accordingly, production is on full stream. With inquiries for the product being received from America and Europe, future prospects for this solar cell are promising.

1.8. Rules of Thumb for Developmental Success

From the novel yet limited experience cited, the author thinks the following are important to successfully develop a new, scientifically-advanced device:

(I) Develop an innovative device: it is important to take the initiative in the international academic world,

(II) Secure the cooperation of a powerful division of applications: a self-limiting rootless approach will yield no results,

(III) Cultivate the market: A "missionary zeal" is needed during the early stages of cultivation,

(IV) Develop a creative and efficient manufacturing process: unless supported by such manufacturing process, the development of new devices (sensors, etc) is sure to fail,

(V) Set-up and start-up manufacturing facilities and manufacturing organization at the right time: these factors are the keys to assure market shares and profits.

The following is a supplementary explanation:

(1) Stages (I) to (V) can be done by a single person from start through to completion (marathon method) or by different people stage by stage (relay method).

(2) To ensure success, the best way is for a manager who is strong in (II) and (III) to guide (I) and do (IV) and (V) in cooperation with good partners.

(3) A manager who is strong only in (I) may, in many cases, find himself short of ideas and ability if he assumes responsibility for (II) and subsequent stages.

(4) (V) is a very important stage because this is where the final touch is given. To ensure smooth implementation of this stage, more personnel, than would normally be required, should be moved from research division to manufacturing division. When production comes on stream, some of those people can return to the research division.

(5) One thing to remember is to discover the next generation of initiators (their development through education is almost impossible), then to help them start (I) and keep a concerned outlook on their activities. This stage is indispensable for continued growth.

(6) The manager himself needs a mentor who will be concerned with the progress. This person is, in effect, the very initiator to promote the undertaking.

2. THE INTRINSIC PROCESS OF INNOVATION

2.1. Stages of Innovation Process

We can find that there have been characteristic periods of innovation process from the experiences of the laser diode (LD) development in our corporation as described in the preceding chapter. The periods are summarized as follows.

Six periods of laser diode developmental work:

- *1st period*: Conceptual proposition of new idea (Prof. Nishizawa). (The farther from the ordinary framework the idea is, the bigger the impacts are expected.),
- *2nd period*: Verification of idea into the real. (First pulsating motion was confirmed in the liquid nitrogen cooled atmosphere. GE, IBM, MIT.),
- *3rd period*: Realization in the ordinary environment of use. (A hetero-junction structured LD [Kroemer] and double hetero-junction structured LD [Hayashi] are operated at room temperature.),
- *4th period*: Improvement of reliability and usability. (Long life-time 10,000 hr and low current 20mA LD. Mitsubishi.),
- *5th period*: Development of creative and efficient fabrication process. (First fully-automatic assembly and inspection line. Mitsubishi.),
- *6th period*: Establishment as a key component for a specified system. (LD is usable for a pickup of a compact disc player).

Now consider the innovation process from another view point. From these facts which we have learned it is found that the innovation is going on along a series of evolving stages. The innovation follows an evaluational process, in which it is born, grown up and preveiled into the society. From this evolution point of view, we propose that the innovation process can be essentially represented by the four stages, which we call the stage model as illustrated in Figure 1.

The four stages are:

Stage I	Jumping off from the ordinary framework,	<Discontinuity>
Stage II	Recurrence to the ordinary framework,	<Continuity>
Stage III	Growing up into a system,	<System>
Stage IV	Civilization.	<Metasystem>

Jumping off stage

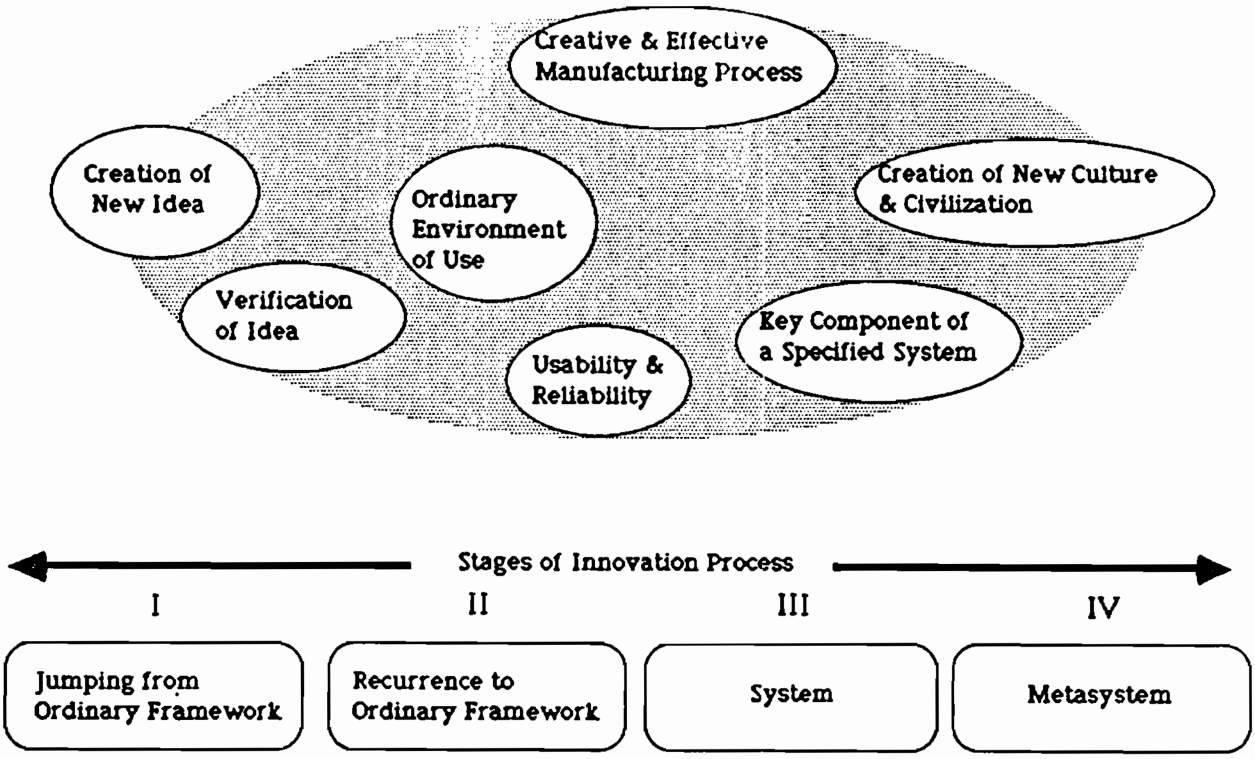

Figure 1. The Four Stages of Innovation Process

When a idea is born, whether it is innovative or not depends on how far it is from the ordinary order at that time. This implies that it is essential to cut off and jump from the existing framework of concepts and methodologies on which the technologies are based at that time. So it is important to discontinue the usual stream of thinking and view points.

Recurring stage

No matter how innovative the idea is, it is insignificant without being realized in the ordinary environment of use not in the specific environment like an experimental laboratory. It implies that the idea born by cutting from the ordinary order should be recurred to the ordinary order; usability and reliability are achieved.

System stage

It is necessary to systemize the idea into a new product and establish a stable manufacturing system, and the new idea is introduced into the marketplace. The laser diode, for example, becomes a key component of a compact disc player and the new fabrication system is developed.

Metasystem stage

Once the new developed product is accepted by the consumers, the product use is spread into the society. This happens often to change the social culture. For instance, the present electronics civilization could replace the photonics civilization in the future with the spread of LD and other photo devices. The innovation has possibilities to crate the metasystem; new culture and new civilization.

This stage model holds true in another case as well as the case of laser diode development. For instance, the development of electric light bulb can be explained by stage model. The first stage is considered to be the invention of bamboo filament by Thomas Edison and tungsten filament. The second stage is the improvement by gas charged bulb, frosted glass and double coiled filament. The third stage is the construction of the electric transmission and distribution systems through a city, by which a whole electric utility system is established. The fourth stage is the electric utilization for lighting, heating and communication which have created the electric and electronics civilization.

2.2. Revisit the Existing Innovation Model

R.K. Mueller classified the kinds of innovation into three types:

1. Breakthrough type,
2. Nuts and Bolts type,
3. System type.

Following our stage model, the first 'breakthrough' type corresponds to stage I (Discontinuity), the second 'nuts and bolts' type corresponds to stage II (Continuity), and the third 'system' type corresponds to stage III (System) and IV (Metasystem).

The other traditional model is the innovation cycle which consists of four activities: Research, Development, Manufacturing and Distribution as shown in Figure 2.

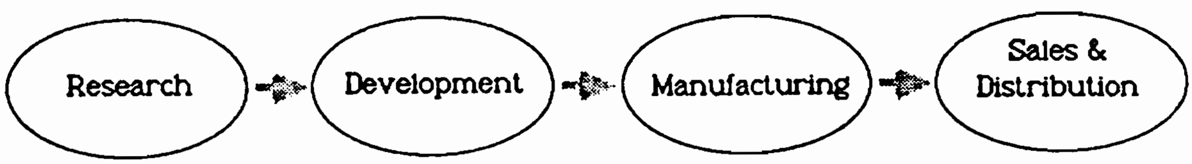

Figure 2. Innovation Cycle

This cycle model can also be considered in comparison to our model. The research activity corresponds to stage I. The development activity corresponds to stage II. The manufacturing activity corresponds to stage III. The sales and distribution activity corresponds to stage IV.

As the innovation cycle model is simple and linear it is widely accepted. Meanwhile, the real innovation process is not so simple and linear and it is pointed out that mutual and feedback interactions among activities exist, and alternative cycle models are proposed. For instance, H. Inose presents a network cycle model in which each activity has mutual interactions with each other. F. Kodama presents the spiral model of innovation which represents the innovation advances like a spiral through the four phases.

The nonlinearity is also true to our model. It is not always the case that the innovation advances in linear from stage I through to stage IV.

2.3. The Importance of Debug

The debug is to identify, exclude and improve the errors. It is important to have this debugging function in the innovation process. It should be noted that every activity is depending on people who inevitably commit the mistakes and the deficits. This is the reason why the debug is important in the innovation process.

For the consumer products to obtain the competitive power, it is quite important to have the debugging abilities, especially at the manufacturing process. It is not too much to say that Japanese high competitive power of consumer products has arisen from the fact that this debugging ability is high in manufacturing process. The debugging ability is counting heavily on the human ability, such as intuition, so that it is not possible to realize it on the machine or automation at the current level of technologies. The debugging intuitions of both engineers and workers are cultivated from their sufficient knowledge of the products with affections, and it is characteristic to the Japanese culture, which has resulted from the stable employmentship of Japan, high voluntariness of workers, and their feeling of corporate unity.

3. NEW MANAGEMENT FOR SUCCESSFUL INNOVATION

We have learned the important factors for the successful innovation process from the experiences of laser diode development in our corporation. The important factors are concerned with intrapreneur, transfer and top management.

(1) Role of Intrapreneur:

Intrapreneur is necessary. It manages the whole innovation process and integrates them for the success of industrialization.

(2) Transfer Management:

On transferring from R and D to manufacturing, transferring of human resource is quite important.

(3) Tolerance of Top Management:

Top management is expected to have a broad mind to tolerate the high risk work of an intrapreneur, seeing from the different respects rather than the respects of the short term profit.

The above three factors are all indispensable for the success of the industrialization of innovation. In the following we will discuss the last factor.

3.1. Governance

The profit and efficiency pursuits have usually been the matter of primary concern of the corporate management. Meanwhile, in these days when technology is rapidly changing and the company is big enough to have power of the social and international influences, it is still fundamental but insufficient to think much of the profits and the stockholders as before. The corporate management is now required to have the philosophy of "governance".

Governance is a concern with the assets for the future growth and with the stakeholders who mutually interact either directly or indirectly with the corporation; i.e., stakeholders are all who concerns; stockholders, employee, customer, academic and local society. The phrase "the different respects rather than the respects of the short term profit" described in factor (3) implies this concept of 'governance'.

The governance as well as the creative scientist and technologist is essentially required for the new products development. R.K. Mueller, former chairman of Arthur D. Little Inc. U.S.A., introduced firstly the concept of governance to corporate management in his book *Metadevelopment* (1977) with the best knowledges of the author. The other books are *Governance and Management* (S. Shindo 1983), *Management by Division of the Three Powers* (Itoh, 1984) and *Corporate Governance* (Tricker, 1984). The four key elements of corporate governance are the supervision of executive activity, accountability to legitimate interests, the setting of corporate direction, and involvement in the executive action.

1. Direction of the corporate future,
2. Executive action of the corporate management,
3. Supervision of management,
4. Accountability.

The governance and management of a company is illustrated in Figure 3. in which they are not strictly separated but mutually overlapped.

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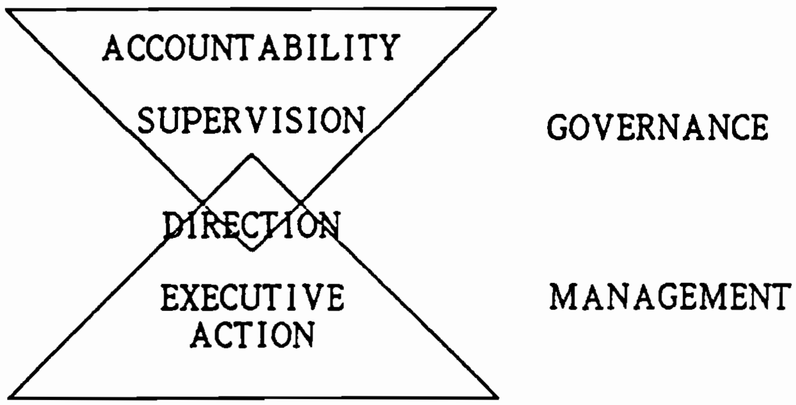

Figure 3. Governance and Management of the Company

3.2. Management of Innovation

The concept of governance makes it clear to have an insight into the innovation management. The following are examples that the corporate management can be seen from two aspects of governance and management.

(a) Principal function of technology administration

As the governance:

- Commitment to the key project of the whole corporate,
- Technology planning: making framework for the corporate future,
- Surveillance and publicity of technology,
- Technology audit.

As the management:

- The execution of R and D.

(b) The role of technical staff

Although it is hard to define the role of headquarters staff, the concept of governance can make their role clear so that:

- As the governance, the roles of staff are terms as listed in above (a),
- As the management, the role of staff is to resolve the conflicts among the divisions.

(c) Basic research

There have been many arguments concerning what the basic research is to be in the corporate dimension. It will be possible to describe clearly with the concept of governance. The author considers that the basic research comes into existence in the contact point between the aspiration of a scientist and that of governance (top management), for the basic research should be different from the current products but not so far from the corporate products. This is the true aspects of the basic research in the author's belief.

(d) Cooperation of University, Industry and Government

The innovation is carried out with the cooperation of the three sections: university, industry, and government. It is considered that the function of each section can be divided into two aspects: governance and management. As shown in Figure 4. each section has mutual relationships with each other through governance and management.

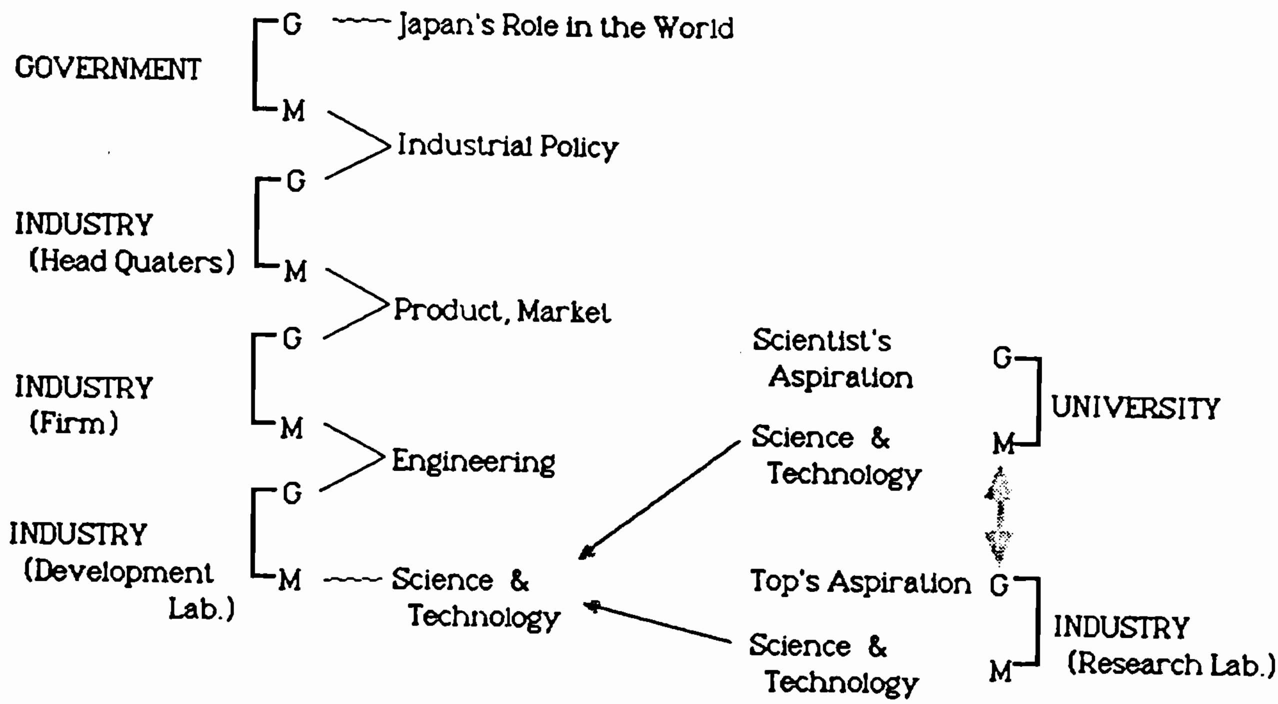

Figure 4. Relationships among University, Industry, and Government through Governance and Management.

4. INNOVATION AND AESTHETIC SENSE "BEAUTIFULNESS"

The innovation is essential for the corporate growth, and it yields the profit of current term in respect of the management and it makes an appropriate guiding principle for the corporate future in respect with the governance.

S. Sugita says that "The change of times follows as the human thinking that is logically inexplainable rather than as a logical consequence or a rational judgement. One of these human senses is the aesthetic sense "beautifulness". The aesthetic sense is an intention, where the human being acts differently or takes another choice from other people, for it has no relish to behave in the same manner with other people".

The innovation is the change. The aesthetic sense works at each stage of innovation process from "Cut off and jump from the ordinary framework" through "Recurrence to the ordinary framework" to the creation of "Metasystem: - new culture and civilization -. It can be said that the innovation is founded on the basis of human aesthetic sense, since it is an activity of the human beings.

Japanese culture has a long and profound history in the broad areas; arts, poem, picture, architecture, and life style. As for the Japanese aesthetic philosophy, R. Oohashi has recently introduced the concepts of "KIRE" (cutting-off, discontinuity in Japanese) and "TSUZUKI" (continuity in Japanese). The "KIRE" is to cut off the stream of the self existence of an object and make it different from the current world, and "TSUZUKI" is to return to the current stream of the world. The art has a structure of composites of "KIRE" and "TSUZUKI", each of which has once been different, but both together create a new world of the beautiful. We can see the typical structure of "KIRE" and "TSUZUKI" in the "NOH", the poem, the picture, the garden and in other masterpieces.

It is possible to say that the "Discontinuity" corresponds to "Jump from the ordinary framework" and the "Continuity" corresponds to "Recurrence to the ordinary framework", and a new-age culture and civilization could be opened by the "Discontinuity and Continuity".

The author would like to say in conclusion that the innovation which we have learned and introduced is now fundamental to the industry of Japan, and it is deeply rooted by the Japanese cultural climate, the key of which is the aesthetic sense of Japanese people who set a high value on the innovative and different concepts from the ordinary. The human aesthetic sense is essential for the innovation in the fields of science, technology and engineering.

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