# Hierarchical Knowledge Transfer and Creation Model

Hideaki Uchikawa[1), 2)], Toshiyuki Yasui[1)], Seiko Shirasaka[1)]

[1)] Graduate School of System Design and Management, Keio University, Yokohama City, Japan

[2)] Japan Aerospace Exploration Agency (JAXA), Tsukuba City, Japan

uchikawa.hideaki@z2.keio.jp

**Abstract.** Knowledge transfer is one of the most widely considered issues in many organizations. Many different methods have been proposed as solutions, but these have not been systematized. So, it is difficult to apply the appropriate method to one's situation, and to perceive one's status and weaknesses. Knowledge management consists of three features: knowledge type (tacit or explicit), architectural layers of knowledge (elemental or systematized) and structural hierarchy of an organization. A knowledge creation model between tacit and explicit knowledge, called the SECI model, was proposed by I. Nonaka and H. Takeguchi in 1995. The SECI model considers the kind of knowledge type, but does not include other features. Architectural layers of knowledge and structural hierarchy of an organization are also important features to consider regarding an organizational knowledge management issue. Consequently, this paper proposes an hierarchical knowledge transfer and management model based on the SECI model that includes all three features. This proposed model is original because it combines the SECI model with an hierarchical organization system based on the systems engineering concept. This model offers a model for organizational knowledge transfer and creation and a guideline to survey knowledge management status and weaknesses of an organization corresponding to the three features of organizational knowledge.

## INTRODUCTION

Knowledge accumulated in documents (explicit knowledge) becomes obsolete due circumstances and technological development over time. Knowledge accumulated in an individual (tacit knowledge) dissipates due to personnel relocation, retirement and loss of knowledge. As a result, knowledge transfer is one of the most widely considered issues in many organizations. Many different methods and models for knowledge transfer and integration have been proposed (Sabherwal et al. 2005). Each method has its advantages and disadvantages, but these have not been systematized to apply a hierarchical organization system. So, it is difficult to apply the appropriate method to one's situation, and to perceive one's status and weaknesses.

A knowledge creation model between tacit and explicit knowledge, called the SECI model, was proposed by I. Nonaka and H. Takeguchi in 1995 (Nonaka et al. 1995). The SECI model is most widely known as a knowledge management model and many studies have applied or modified it.

In this paper, a hierarchical knowledge transfer and creation model is proposed based on the SECI model and applying an hierarchical organization system. This model is 3 dimensional with 3 axes, namely knowledge type (tacit/explicit knowledge), architectural layers of knowledge (elemental/systematized) and organizational layers (individual/project/organization). This proposed model is original because it combines the SECI model with an hierarchical organization system based on the systems engineering concept. This model offers a model for organizational knowledge transfer and creation and a guideline to survey knowledge management status and weaknesses of an organization.

## ISSUES REGARDING KNOWLEDGE TRANSFER AND CREATION METHOD

There are three major issues regarding knowledge transfer and creation methods.

### Non-systematic

Many methods for knowledge transfer and creation have been proposed, such as OJT which is based on practical experience at work, database based on information technology (IT), and lessons learned. But

there are no clear models or guidelines on how to select a method apropriate to one's situation, or how to combine different methods. In 2012, a questionnaire survey was conducted on a group of engineers (n=190) who are/were working for the H-II transfer vehicle (HTV) project. HTV is a unmanned spacecraft used to resupply the international space station (ISS) developed by Japan Aerospace Exprolation Agency (JAXA). In the questionnaire, some examples of knowledge transfer methods were given and the engineers were asked "How effective does this method transfer knowledge to others (degree)," "To how many people can knowledge be transferred by this method (range)" and "How long does this method transfer knowledge to others (time length)." Figure 1 shows the summarized results. Strength of these features is given in relative values from 0 to 3. From the results, OJT was considered to be the best method to transfer knowledge, but is weak in range and time length. Document, IT, product and training course are assumed to have advantage in range, but show weakness in degree and time length. As can be seen, each knowledge transfer method has advantages and disadvantages, so combining them into a system for knowledge transfer and creation is needed.

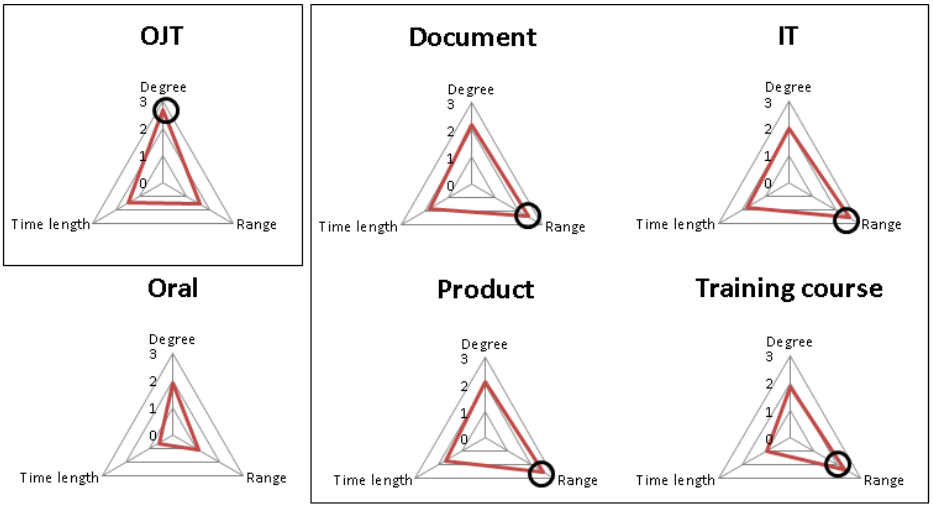


Figure 1. Example of knowledge transfer characteristics based on a questionnaire given to 190 engineers in HTV project

### Lack of Sustainability

In the example shown in Figure 1, no method showed a high degree for time length, suggesting that none of these methods is effective for a sustainable length of time. Also, project type organization can be terminated, leading to a large loss of knowledge as human resources dissipate (except in cases where there is a subsequent project with the same members). This is one major factor in the loss of organizational knowledge in project type organization. Hence, a knowledge transfer system which enables an organization to utilize knowledge created in a project is needed.

### Weak understanding of the situation

From the viewpoint of the entire organization, knowledge transfer and creation methods are not implemented systematically, so it is difficult to understand where and how much is knowledge accumulated, the status of activities to retain knowledge, and whether such conditions are sufficient. This is more noticeable in larger organizations, so a model that can consider knowledge transfer and the creation situation of an entire organization is needed.

## BASE MODELS

### Knowledge transfer and creation model (SECI model)

The SECI model is a knowledge creation model developed by Nonaka. In this model, tacit and explicit knowledge are not simply divided, but enables knowledge creation through management which encourages interaction between the two types of knowledge. The SECI model consists of 4 processes-

Socialization which creates new tacit knowledge by sharing individual experiences in a group or team, Externalization which converts tacit knowledge into clear concepts (explicit knowledge), Combination which combines different concepts into one knowledge system, and Internalization which enables an individual to acquire explicit knowledge and convert it into tacit knowledge (Figure 2). Each process requires a different "Ba", representing shared space, either physical, virtual, mental or any combination, that serves as the foundation for knowledge creation (Nonaka et al. 1998). In the SECI model, knowledge creation is not just one cycle, but has many cycles, so it is a sustainable knowledge transfer and creation model.

However, when applying the SECI model to an organizational structure, how to apply the model and to which situation or organizational layer is not clear. For instance, socialization is a process to create new tacit knowledge within a group or team. The question is that if the group creates new tacit knowledge at some point in time, what is its position in the organization? A holistic view of the organizational layer is needed when considering issues regarding knowledge transfer and creation.

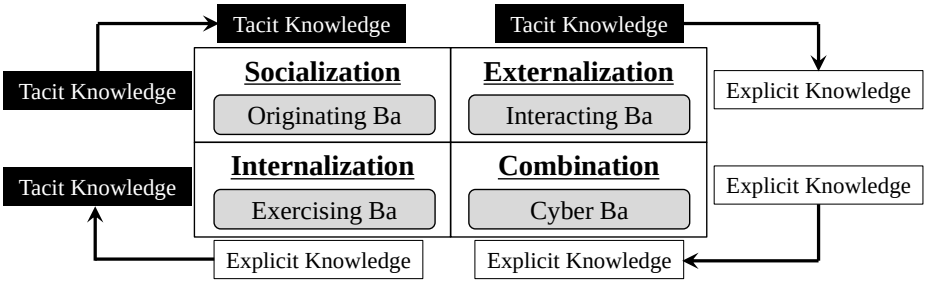


Figure 2. SECI model with "Ba" (from Nonaka et al. 1995 and Nonaka et al. 1998)

## Organization model

PIMBOK defines organizational structure types as functional, project, matrix, or their combination (PMI 2008). Each organizational structure has 3 components- individual, project team, or functional division and organization. So, the proposed model in this paper is based on an organizational structure with three layers "individual – project or functional division (project) – organization" (Figure 3). When this organizational structure is applied to a systems engineering concept, the entire organization is the system, a project or functional division is a subsystem, and an individual is the lowest configuration item (LCI).

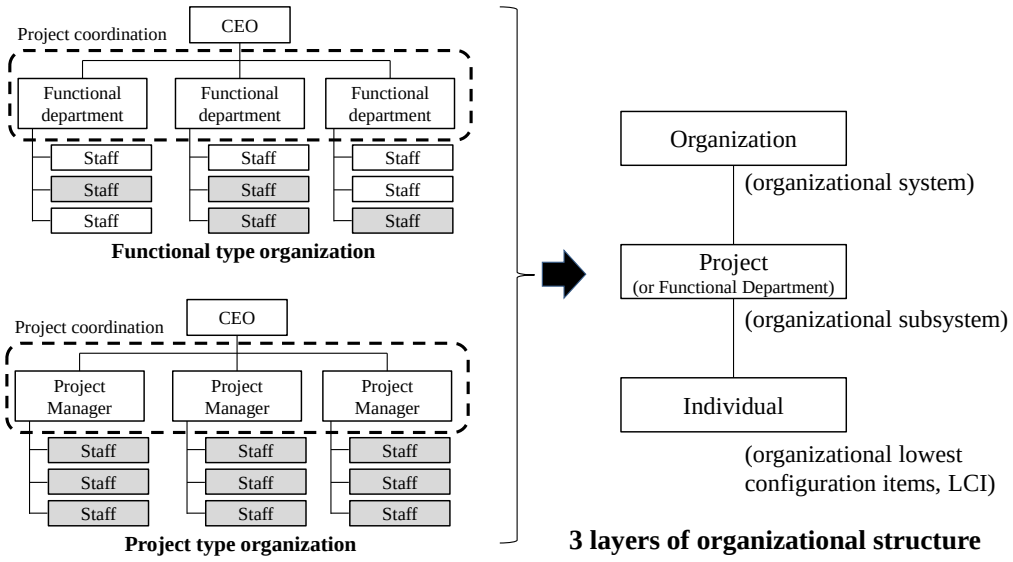


Figure 3. Three-layer organizational structure

## HIERARCHICAL KNOWLEDGE TRANSFER AND CREATION MODEL

### Overview

A hierarchical knowledge transfer and creation model (Figure 4) that applies the SECI model to the organizational structure shown in Figure 3, is proposed. The SECI model has 4 processes per cycle on a 2 dimensional plane (Figure 2), and is based on the knowledge transfer concept between tacit and explicit knowledge. In contrast, the proposed hierarchical knowledge transfer and creation model has a 3-dimensional structure. The three axes are knowledge type (tacit/explicit knowledge), architechtural layers of knowledge (elemental/systematized) and organizational layers (individual/project (including functional division)/organization). In addition, a node is defined as a knowledge entity, and is symbolized as n(i,j,k) where i, j, k are elements of each axis. The path from one node to another corresponds to the knowledge transfer method or process. Every path includes a "Ba".

This proposed model, which is based on an actual organizational structure, enables each knowledge entity and knowledge transfer process to be defined in detail and is more practical than the conventional SECI model. It can be a guideline model enabling an organization to develop the appropriate strategy for knowledge management.

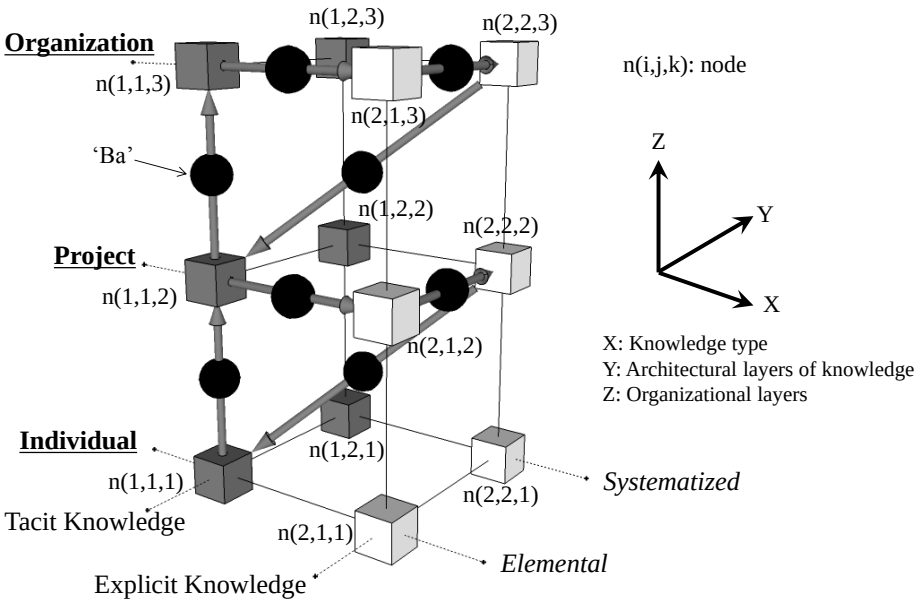


Figure 4. Hierarchical knowledge transfer and creation model based on the SECI model

### Axes

As shown in Figure 4, the hierarchical knowledge transfer and creation model has three axes. The X-axis is the knowledge type and has two elements, tacit and explicit knowledge. The Y-axis is for architectural layers of knowledge and has two layers of knowledge, systematized and elemental knowledge. The knowledge structure can be divided into more layers as needed. The Z-axis is the organizational structure, with an individual considered to be the lowest configuration item, LCI. A project team or a functional division is a higher layer in the organizational structure, and the highest layer is the organization itself. Though there may be more layers in a real organization, such as departments and subteams in a project, the organization is considered with three organizational structural layers for simplicity. The relationship between the system and the subsystem is relative, so this model can be applied to an organization which has more layers.

### Nodes

Each node, n(i,j,k), is a knowledge entity with three components; knowledge type, architectural layers of knowledge, and organizational layers. For instance, n(1,1,1) represents "tacit knowledge/elemental/individual" such as personal experience or know-how of an object/matter. Table 1

shows knowledge entity examples corresponding to each node. Although knowledge entities are different for business fields or organizations and there are many variations, the overall structure can be generalized.

Table 1. Knowledge entities

| Node # | Description | Knowledge entity example |
|---|---|---|
| n(1,1,1) | Tacit K./*Elemental*/**Individual** | Personal experience of an object/matter |
| n(1,1,2) | Tacit K./*Elemental*/**Project** | Common sense in a team |
| n(1,1,3) | Tacit K./*Elemental*/**Organization** | An abbreviation for an object/matter |
| n(1,2,1) | Tacit K./*Systematized*/**Individual** | Personal behavior regarding work |
| n(1,2,2) | Tacit K./*Systematized*/**Project** | Operation know-how of a team activity |
| n(1,2,3) | Tacit K./*Systematized*/**Organization** | Organizational culture |
| n(2,1,1) | Explicit K./*Elemental*/**Individual** | A personal note of an object/matter |
| n(2,1,2) | Explicit./*Elemental*/**Project** | Project meeting procedures |
| n(2,1,3) | Explicit./*Elemental*/**Organization** | Organizational contract regulations |
| n(2,2,1) | Explicit./*Systematized*/**Individual** | Research papers |
| n(2,2,2) | Explicit./*Systematized*/**Project** | Project finalization materials |
| n(2,2,3) | Explicit./*Systematized*/**Organization** | Organizational standards |

**Paths**

The path from one node to another corresponds to the knowledge transfer method. For example, a path from n(1,1,1) to n(1,1,2) is a path from "tacit knowledge/elemental/individual" to "tacit knowledge/elemental/project" such as brainstorming in a team on an elemental issue. This path corresponds to the Socialization process in the SECI model. Another example is a path from n(1,1,2) to n(1,1,3). This path is a knowledge transfer process from "tacit knowledge/elemental/project" to "tacit knowledge/elemental/organization." Although the organizational structural layer is different, one layer high, it is also the Socialization process if the project team is viewed as an individual. An example of a path is a meeting or brainstorming for a techinical field with members from several project teams. Examples of paths corresponding to each knowledge transfer process are shown in Table 2. As shown in the table, 4 knowledge transfer processes in SECI model can be clearly seen if an organizational structure is taken into account. In addition, some processes may not be expressed in the SECI model, such as a path from n(2,1,1) to n(2,1,2) which is a path from "explicit knowledge/elemental/individual" to "explicit knowledge/elemental/project." An example of this prosess is text mining from personal e-mails.

**"Ba"**

"Ba" should be designed and prepared according to each knowledge transfer process. For instance, a knowledge transfer process from n(1,1,1) to n(1,1,2) requires a "Ba" which provides team members the opportunity to hold discussions and brainstorm. Regular team meetings is also a "Ba". In another case, from n(1,1,2) to n(1,1,3), a "Ba" to discuss and share experiences with members from several project teams as an organizaion is necessary. Examples of "Ba" corresponding to each knowledge transfer path are shown in Table 2. As shown in the table, "Ba" should be designed and managed according to each situation, and should be sustainable.

Table 2. Knowledge transformation paths corresponding to SECI model processes

| FROM | TO | Path example | "Ba" example | Path name in SECI model |
|---|---|---|---|---|
| n(1,1,1) | n(1,1,2) | Brainstorming in a team | Weekly team meeting | Socialization (in project) |
| n(1,1,2) | n(2,1,2) | Technical document creation | Review system of a technical document | Externalization (in project) |
| n(2,1,2) | n(2,2,2) | Project reviews in milestone | Project review material | Combination (in project) |
| n(2,2,2) | n(1,1,1) | Experience in the next phase activity of a project using previous review output | Practical project activiy | Internalization (in project) |
| n(1,1,2) | n(1,1,3) | Exchange project experience in an organization | A working group activity for a technical area with some project teams | Socialization (in organization) |
| n(1,1,3) | n(2,1,3) | Making a report of a working group discussion result | A working group activity for a technical area with other project teams | Externalization (in organization) |
| n(2,1,3) | n(2,2,3) | Making an organizational standard document by systematizing working group reports and discussions | A working group activity for a technical area with other project teams | Combination (in organization) |
| n(2,2,3) | n(1,1,2) | Application of an organizational standard to a project activity with tailoring as needed. | Practical project activity | Internalization (in organization) |

**Synthesizing as a system**

In cases where the entire organization is considered as a system, project teams as subsystems, and individuals as LCI, it is difficult to manage the cycle of knowledge transfer and creation based on the SECI model, if each knowledge transfer method or entity is handled independently. So, a knowledge transfer and creation model corresponding to actual organizational structure with sustainability and hierarchical structure is needed.

**Methods of utilization**

There are two methods of utilization of the proposed model. The first is to set it as a model for the entire organizational knowledge and creation activity. This application enables an organization to gain an overall view of the knowledge management system by considering knowledge entities, knowledge transfer paths and "Ba"s comprehensively. The second is to consider the model as a guideline to evaluate the organizational knowledge management status and take the appropriate countermeasures. For instance, knowledge entities and transfer processes can be surveyed using this model. By comparing these with the standard model, weak points of an organization can be externalized, and the appropriate countermeasures and strategies of organizational knowledge management can be determined.

## RESULT AND DISCUSSIONS

### A case study

As a case study of an organizational knowledge management situation using the proposed hierarchical knowledge transfer and creation model, the data evaluation process of a spacecraft vibration test, (a test to verify spacecraft design when carried by a launch vehicle in the take off launch environment), is considered (Figure 5). In this figure, the 3D model is converted into a 2D model for simplicity. As mentioned above, when considering three organizational structure layers, indivdual-project-organization, there are two cycles of knowledge transfer and creation, namely the individual-project cycle and the project-organization cycle. Actual experience is implemented by an individual. In this case, the vibration test is a "Ba" for individual experience.

First, the individual-project cycle is detailed. Individual experience and knowledge acquired by the vibration test is collected as individual tacit knowledge. Response acceleration data of a test sample showed due to characteristics of the test facility, which should be taken into account for data evaluation. In the future, a survey of the characteristics of the vibration test facility is important. This is an example of individual-elemental tacit knowledge. Another example is how to determine the resolution of a frequency analysis, because frequency resolution affects the frequency analysis graph. These are examples of elemental tacit knowledge of an engineer when evaluating vibration test data. Having such tacit knowledge or experience, an engineer then attends a data review meeting with other team members. The data review meeting is a "Ba" for knowledge transfer from n(1,1,1) to n(1,1,2), in other words, socialization. At the test data review meeting, other engineers to join in with their own different individual-elemental tacit knowledge to evaluate test data. Together, the engineers discuss how to evaluate the test data based on their tacit knowledge. A team discussion provides a multi-perspective in data evaluation, and the process and results of the discussion become shared awareness in the team, leading to tacit knowlede in the project layer. The test data review results are transferred to project explicit knowledge as minutes (Externalization). The test data review meeting is also a "Ba" for externalization, so Socialization and Externalization are implemented simultaneously. Other explicit knowledge in the project layer is collected from the vibration tests for other equipment. Common technical knowledge acquired by some vibration test cases are consolidated into the criteria for vibration test evaluation as a common rule (Combination). In order to document the technical criteria, it must be systematized knowledge, not simply a combination of individual experiences, and the technical background must be reinforced with technical studies. Criteria for vibration test data evaluation is applied to subsequent vibration tests in a project, and can be conducted effectively with previous knowledge (Internalization). When other new knowledge is acquired, it is input in the next cycle, and activities are implemented susitainably and spirally until a project team finalization.

Next, the project-organization cycle is detailed by considering one layer above the individual-project layer, namely the knowledge transfer and creation cycle between project teams and the organization. Project elemental tacit knowledge in this case is shared awareness of the vibration test data evaluation in the spacecraft project, and there is some shared awareness corresponding to each project. Members from several project teams with individual experience and tacit knowledge form a working group, which creates a Ba in Figure 2, in a structural technical area (Socialization). In this case, documents of criteria for vibration test data evaluation in each project are referred to during the working group activity. This knowledge transfer path, from n(2,2,2) to n(1,1,3), is not included in the individual-project cycle. Output by a working group is documented as minutes (Externalization). A "Ba (Interacting Ba)" in this case is also a working group. After releasing discussion results of some technical issues, these are systematized and consolidated to an organizational explicit knowledge, that is a vibration test standard in a organization (Combination). "Ba" for combination, Cyber Ba, in this case, also a working group. A test standard is applied to the actual project activities and vibration tests in each project (Exercising Ba), and general standards are tailored to each project in considerationi of the situation (Internalization).

In order to construct an overall and consistent knowledge transfer and creation system applicable to an entire organization, designing knowledge transfer paths, including their operability, according to the "Ba" for the entire flow of knowldge transfer and cycles of the individual-project-organization, is a key factor.

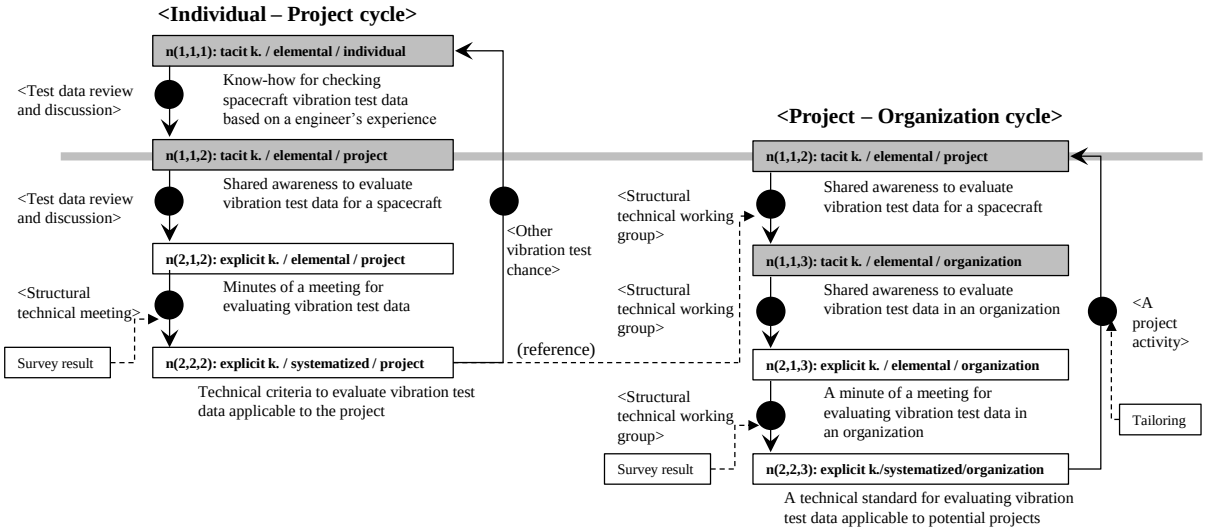


Figure 5. A case study analyzing the application of the hierarchical knowledge transfer and creation model; spacecraft vibration test data evaluation case

## Dicussion

1. Presence of unused nodes or paths in the proposed hierarchical knowledge transfer and creation model when SECI model processes are applied.

For instance, individual knowledge such as n(2,1,1) and n(2,2,1) are not utilized. These may contain much valuable information, so consideration on how to extract and insert them into the knowledge transfer and creation process is needed.

2. Presence of different knowledge transfer and creation cycles from the SECI model one, such as a cycle: n(1,1,1)-n(2,1,1)-n(2,2,1)-n(2,2,2).

In these cycles, individual-elemental tacit knowledge is converted to individual-elemental explicit knowledge, n(2,1,1), such as personal notes or e-mails. Elemental explicit knowledge in an individual produces systematized explicit knowledge in an individual by the knowledge transfer path, from n(2,1,1) to n(2,2,1). An example of systematized explicit knowledge through a person is a technical report or a research paper documented by an individual engineer. This is a source to acquire systematized explicit knowledge in a project, n(2,2,2). The feature of this cycle is that 3 of the 4 knowledge transfer paths can be managed by an individual. That is, if it is difficult for members to gather in one place for one reason or another, such as distance, it may be possible to apply this cycle as an alternative method. Another example is the case of a cycle, n(1,1,1)-n(2,1,1)-n(2,1,2)-n(2,2,2), where elemental individual data such as private notes or e-mails are converted to elemental explicit knowledge in a project. Text mining is one method for this path. Then, by extracting or systematizing key factors, they are transformed to the systematized explicit knowledge in the project. Some cycles can be combined.

## Future Activities

1. Improve the validity of verification of the proposed model.

In this paper, a case study of spacecraft vibration test data evaluation is shown. Howevern this is not sufficient. One idea is to interview various organizations regarding method or system for organizational knowledge management, and or apply them to the proposed model.

2. Utilization of unused nodes, paths and cycles.

A detailed survey is possible.

3. Expand the proposed hierarchical knowledge transfer and creation model by adding functional views to its organizational structure.

Figure 6 shows an example of a simplified spacecraft project team structure from the viewpoint of technical functions. The project team can be divided into functional subsystems, such as structure, thermal control, power, etc., and a functional system which consolidates the functional subsystems.

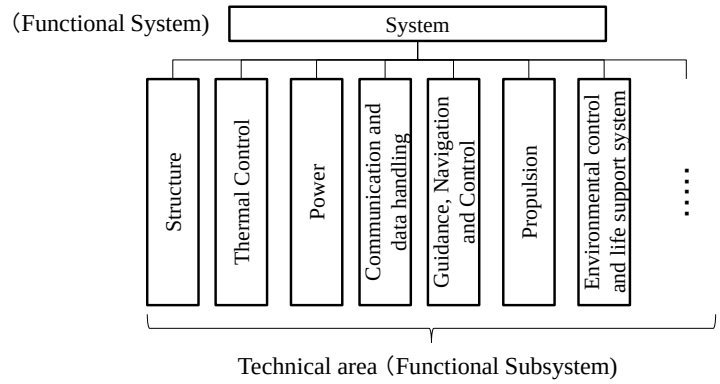


Figure 6. An example of spacecraft project team functional structure

Each functional system and functional subsystem is considered to be included in the proposed hierarchical knowledge transfer and creation model. Figure 7 shows this concept.

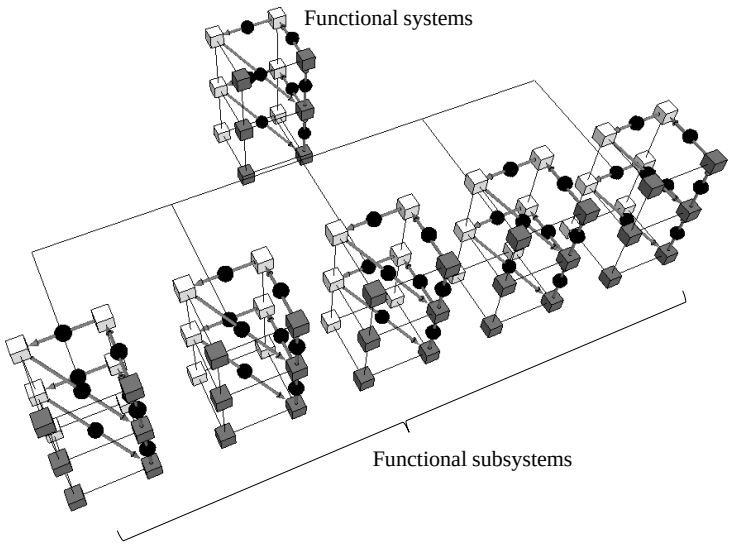


Figure 7. Concept of an enhanced hierarchical knowledge transfer and creation model based on the project functional structure

## CONCLUSION

In this paper, a hierarchical knowledge transfer and creation model is proposed, based on the SECI model applying organizational system hierarchy. This is a model for organizational knowledge transfer and creation and a guideline to survey knowledge management status and weaknesses of an organization. Three future activities have been identified- the need for further verification, a survey on the utilization of unused nodes, paths and cycles, and expansion of the proposed model by adding functional views.

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## BIOGRAPHY

Hideaki Uchikawa is a 2nd year master's student at the Graduate School of System Design and Management (SDM), Keio University. His interest is knowledge management for project type organization for sustainability. Mr. Uchikawa is also an associate senior engineer in Next generation space vehicle research office, Space vehicle technology center, Human space flight mission directorate, Japanese Aerospace Exploration Agency (JAXA), Japan. He has 10 years of experience in H-II Transfer Vehicle (HTV) project, an unmanned space vehicle used for resupplying the International Space Station (ISS).

Toshiyuki Yasui is a Special Research Professor, Keio University Graduate School of the Systems Design and Management. Prior to his current position, he served as Councilor of the Financial Services Agency (2008–2009). Upon graduating from the University of Tokyo with a BA in International Relations in 1985, he joined the Japanese Ministry of Finance and spent 25 years at various government posts. His interests include systems approach to public policy, social systems theory, and systems of finances and currencies. Prof. Yasui also serves at the National Graduate Institute for Policy Studies of Japan as a Visiting Professor.

Seiko Shirasaka is an associate professor of Graduate School of System Design and Management at Keio University. He received his M.S. degree in the field of Astronautics from Tokyo University in 1994 and immediately joined Mitsubishi Electric Corporation. Since then, Prof. Shirasaka has worked for several space system development projects as a systems engineer for 15 years. His research interests include Architecting methodology for technical systems and social systems, system assurance design and very small satellite design methodology.

## CONTACT INFORMATION

E-mail: uchikawa.hideaki@z2.keio.jp