Effective training methodology for satellite operation

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Satellite LEOP operation requires many operators with different specialties to properly conduct the demanding operations such as satellite control, flight dynamics, mission equipment operations, and other operations. Each of these operators has specialized backgrounds, skills and knowledge. Therefore, some satellite operators may only know a little about the ground system while some ground system operators may only know a little about the satellite system. It is of no doubt that training is necessary to ensure the operators obtain the necessary skills and knowledge for smooth and reliable satellite operation. However, the training of satellite operators tends to pose a dilemma in balancing its necessity with limited budget and time constraints. For LEOP operation training, the operators may number around 400 people, with many of them also responsible for pre-launch preparations, thereby being too busy with those duties to attend the operator training. At JAXA's request, an equally effective and efficient training methodology has been developed and applied by SED (Space Engineering Development Co., Ltd.) over the course of three JAXA satellite projects. The methodology was successful in reducing the cost of training while also improving its quality. Effective planning consisting of web-based self-training and practical training is the major element of this training. At the planning stage, the skill map clarified training items in order to avoid unnecessary training of the operators. As a result, excessive training was removed, successfully reducing the manpower cost. The web-based self-training mitigated the time investment and provided greater flexibility, more effectively training the operators. In the practical training, a satellite simulator was used to simulate virtual TT&C operation. This simulator use also resulted in an increased internalization of the skills required by the operators. In this paper, the methodology of the training, along with its effects and results are introduced and discussed.

I. Introduction

FOR a given satellite project the number of LEOP operators is quite high. In JAXA, the numbers of operator may number as many as 400 people. Many of operators are associated not only with the LEOP operation, but with launch preparations as well. Earlier training sessions have proven that some operators could not attend training due to their duties with launch preparations.

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JAXA and SED have developed a new training methodology, which has proven to more efficient and flexible than the traditional approach. The methodology has been successful in reducing the total days necessary for training by over 50%. The methodology has now been used in operator training for one earth observation and two geostationary satellites.

The three key features for the effective and efficient training methodology are as follows:

1) The required skills are visualized before and after the training by using a skill map to establish the training program for individual positions to optimize the size of training.

2) The web-based self-training provides flexibility and mitigates the time investment.

3) Virtual TT&C operation training is conducted by using the satellite simulator, which also results in an increased internalization of the skills required by the operators.

II. Training Plan

The training plan was designed as to clearly define the following points:

1) Purpose
2) Enforcement policy
3) Skill map
4) Training item/target position
5) Implementation structure

A. Purpose

The training purpose is set as follows:

> To have operators acquire the operational knowledge and skill necessary to conduct smooth TT&C and mission operations.

The following nine points are the points necessary to successfully meet the training goals:

1) Acquiring the common knowledge required of all LEOP operators

2) Understanding the scope of the work assigned to each position

3) Understanding how to deal with the transaction of business

4) Acquiring system operation skill

5) Acquiring knowledge of the operation procedure for each position

6) Learning the inter/intra-team interface operation procedure

7) Learning the operation procedure for exchanging information along the line of command during satellite critical events/satellite anomaly situations

8) Confirming the adequacy of the satellite operation plan, procedure, and skill acquisition by conducting TT&C operation training

9) Revealing and addressing any underlying operation issues

The nine points are assigned to three training groups to confirm and resolve (see Figure 1 below) with each operation team participating in the training to acquire the necessary knowledge and operation skill. The training starts with General Knowledge Training and finishes with TT&C operation training. TT&C operation training serves to verify the overall readiness for the operation, so the participants and system used are the same as real operations. In the event any underlying issues or problems are found, supplementary training is conducted.

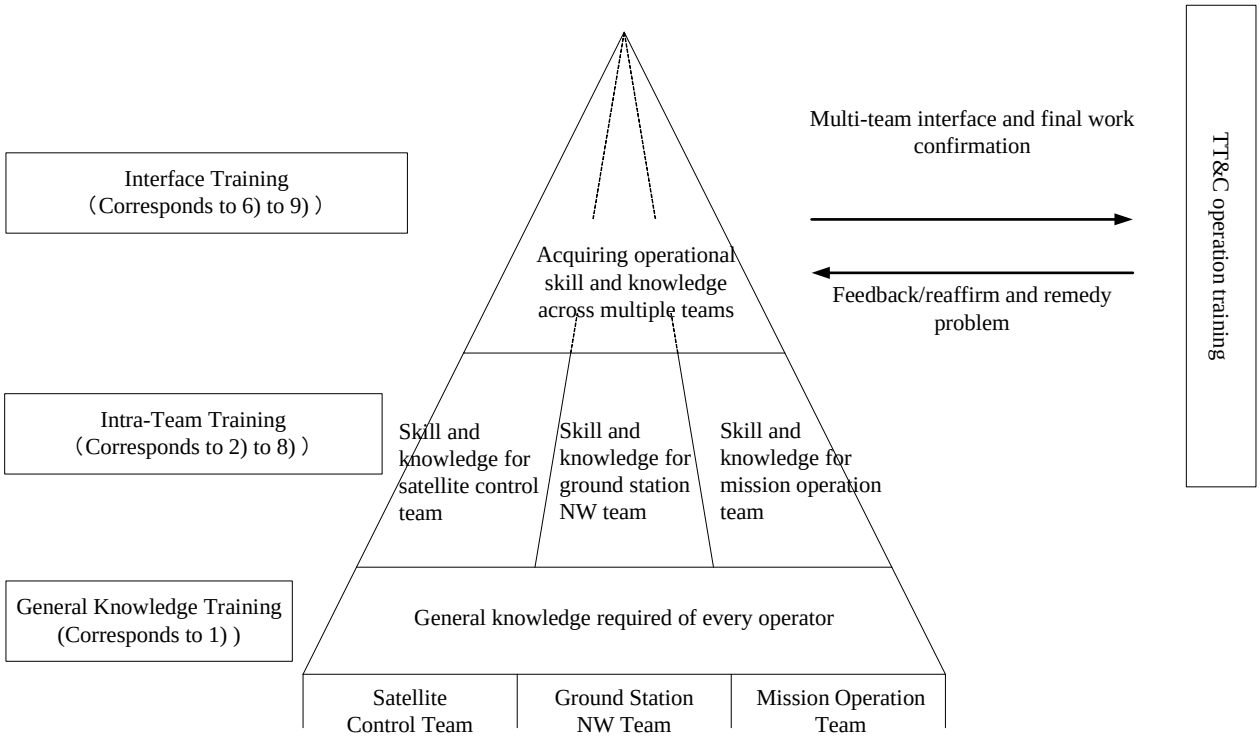

Figure 1. Training Composition

B. Enforcement Policy

The enforcement policy is shown below. Figure 2 shows the training group.

1) Operators have different backgrounds/operation skill/knowledge, so the training items were established taking the required skill/knowledge and individual position into consideration. The number of training items and the number of participants for each part of training are optimized and minimized.

2) Training contents consist of a general knowledge of target satellite operation, internal team enforcement structure, and operation interface/procedure, including anomalous correspondence.

3) Training consists of web-based self-training and practical training. Classroom training is only conducted to the minimum degree necessary. The web-based self-training makes it possible to be performed off-site, such as a participant's home or workplace.

4) Determining and setting the training items associated with the required skill for each position, so that no unnecessary training is conducted.

5) Evaluating the result and effectiveness of training and providing supplementary training as necessary.

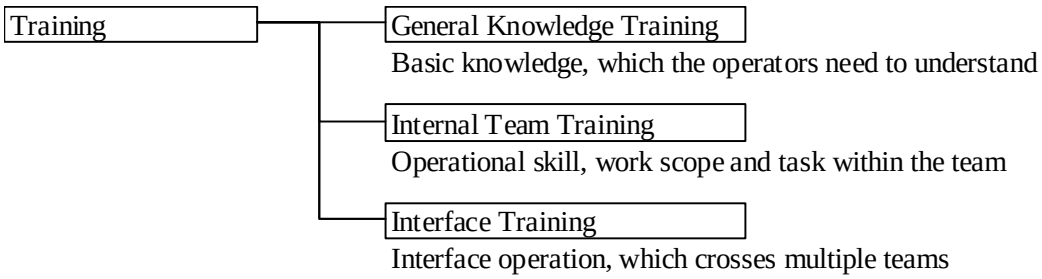

Figure 2. Training Group

C. Implementation Structure

The training is implemented by three groups: the Training Working Group, the Training Control Board, and the Operation Team.

Figure 3 shows the implementation structure of the training.

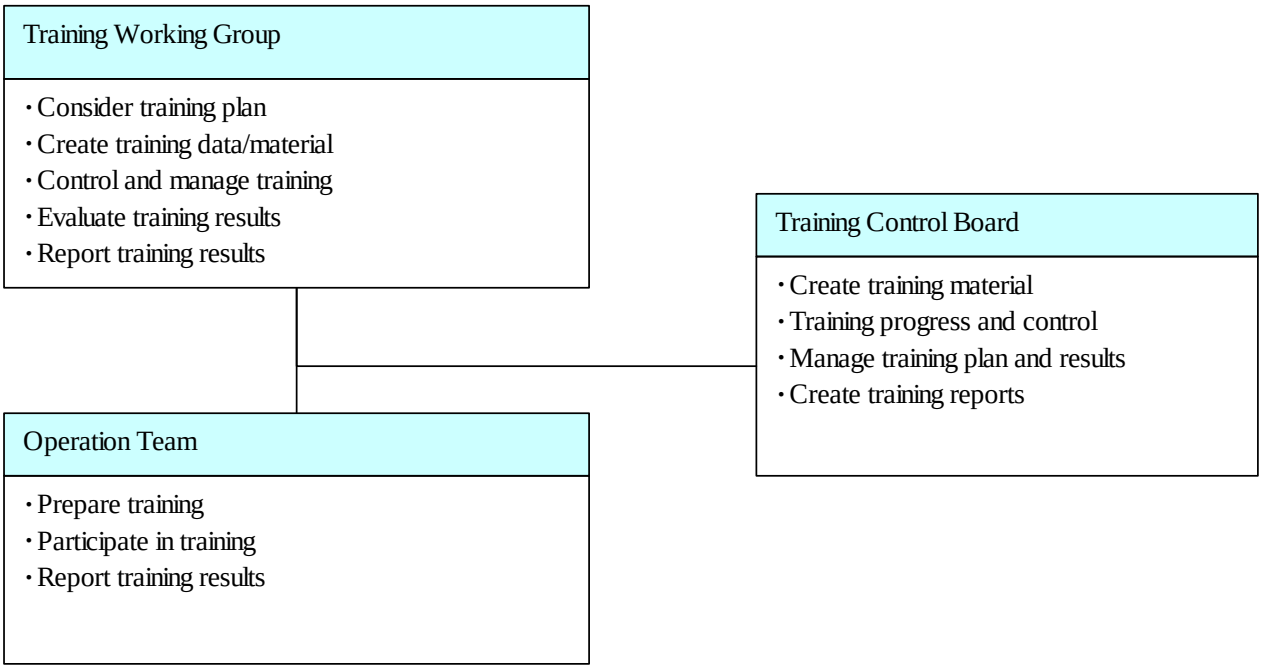

Figure 3. Implementation Structure

D. Skill Map

A skill map is used to clarify the required training items for each position. The role and prequisite skill/knowledge of position are used to determine the required training items. The definition of skill level is used as an indicator of the required skill level. The training methodology is established in order that the skill level of participants reaches the required level as defined by the skill map.

Table 1 shows an example of a skill map for representative positions in a satellite control team. Table 2 shows the training methodology.

Skill level	Definition
a	Having expert knowledge and the ability to make highly-skilled decisions (equivalent to a system developer)
b	Understanding the procedures and having the skill to possibly handle primary correspondence anomalies
c	Having the operation skill/knowledge to conduct smooth operation tasks
d	Having a general knowledge of the particular matter
-	Unnecessary for the particular position

Table 1. Skill Map

Necessary Knowledge/Skill	Position		
	Satellite Operation	Satellite Controller	Sub-system
Knowledge of satellite control team's enforcement structure/split of work	b	b	b
	c	c	-
Knowledge of on-board bus systems	b	b	a
	c	c	a
Knowledge of on-board mission systems	b	b	a
	c	c	a
Knowledge/operation skill of satellite control systems	b	b	c
	c	c	-
Knowledge/operation skill of mission operation systems	c	c	d
	d	d	-
Knowledge/operation skill for ground station NW systems	c	c	d
	c	c	-
Knowledge/operation skill for LEOP satellite operations	b	b	a
	c	c	a

Table 2. Training Methodology

Training Item	Skill Level	Training Material	Training Methodology
Knowledge of enforcement structure/split of work of satellite	d	General knowledge training material	Web-based self-learning
	b	Internal team operation procedure	Web-based self-learning
Knowledge of on-board bus systems	d	General knowledge training material	Web-based self-learning
	b	Satellite operation handbook	Web-based self-learning
Knowledge of on-board mission systems	d	General knowledge training material	Web-based self-learning
	b	Satellite operation handbook	Web-based self-learning
Knowledge of satellite control systems	d	General knowledge training material	Web-based self-learning
	c	Manual (common function)	Web-based self-learning
	b	Manual (satellite peculiar function)	Web-based self-learning
Operation skill of satellite control systems	c	Manual (common function)	Practical training for common function
	b	Manual (satellite peculiar function)	Practical training for satellite peculiar function
Knowledge of mission operation systems	d	General knowledge training material	Web-based self-learning
	c	Manual (common function)	Web-based self-learning
	b	Manual (satellite peculiar function)	Web-based self-learning
Operation skill of mission control systems	c	Manual (common function)	Practical training for common function
	b	Manual (satellite peculiar function)	Practical training for satellite peculiar function
Knowledge of ground station NW systems	d	General knowledge training material	Web-based self-learning
	c	Interface operation procedure	Web-based self-learning
	b	Manual	Web-based self-learning
Operation skill for ground station NW systems	c	Manual (common function)	Practical training for common function
	b	Manual (satellite peculiar function)	Practical training for satellite peculiar function
Knowledge for LEOP satellite operation	d	General knowledge training material	Web-based self-learning
	b	Satellite operation handbook	Web-based self-learning
Operation skill for LEOP satellite operation	b	Satellite operation handbook	TT&C operation training to understand satellite peculiar

III. Web-based self-training

In the previous training style, classroom lectures dominated the bulk of training time. Web-based self-training aims to teach the common knowledge listed in the SOOH (Spacecraft Orbital Operations Handbook) and procedures. The web-based self-training replaces the classroom lecture, which mitigates both the time and cost of training.

A. System

The training participants can access the web-based self-training system remotely via the internet. The training participants can study at times convenient to them, while still making the final preparations and adjustments for the actual operation. The training system also serves to consolidate information regarding the learning status, results of confirmation tests, and can send automatic e-mail notices, all which help rationalize and streamline the work of the Training Control Board.

B. Contents

The contents of training are the study of the training material and confirmation tests to verify the level of understanding (see Figure 4). The training participants study the learning material (e.g. a PDF file) and take the confirmation test. The required courses differ by position, with courses being assigned in accordance with the skill map. The participants complete the course by passing the confirmation test. The types of question were cloze test, multiple choice, yes-no questions, et cetera. The test questions cover the matters necessary for operation and avoid problems simply covering figures and the like.

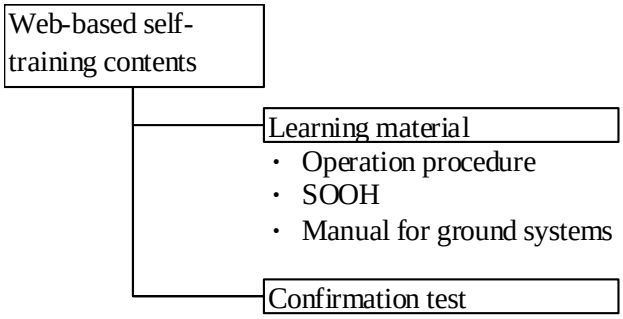

Figure 4. Web-based self-training contents

IV. Practical and TT&C operation training

The practical training aims are that the training participants acquire the necessary operation skill for the system. After they complete the practical training, virtual TT&C operation training is conducted to verify the overall readiness for operation. In the event procedures are changed as a result of TT&C training or any other underlying problems or concerns are found, supplementary training is conducted.

A. Practical Training

The practical training can be most effective when the individual participant operates the actual system with simulated data under an instructor's direction. It may be not possible, however, for some systems to provide this environment. In this case, the Training Control Board must put extra effort into improving efficacy of training, for example showing the instructor's demonstration on the big screen.

The practical training starts with individual system training and interface training. The training order is determined so as to use the created data in the latter stages of training (see Figure 5). The output data of the earlier operation processes (orbit determination and orbit data creation) can be used in the latter operation processes (satellite operation plan), which makes the training preparation even more efficient.

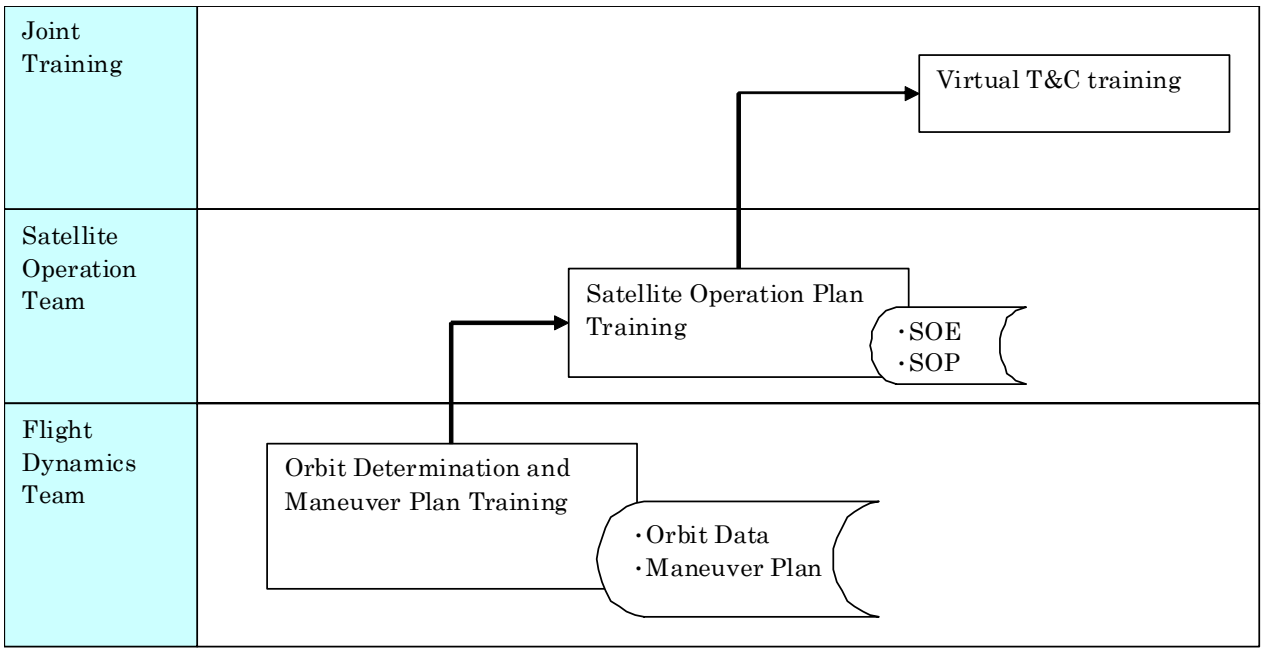

Figure 5. Joint Training Contents

B. TT&C Operation Training

TT&C operation training serves as the readiness check for the overall operation. The satellite simulator provides simulation data. Two kinds of TT&C operation training are conducted (see Figure 6). The Training Control Board distributes information covering cases not preventive in simulation training. For geostationary satellite training, the eventless duration is skipped when making the training time line.

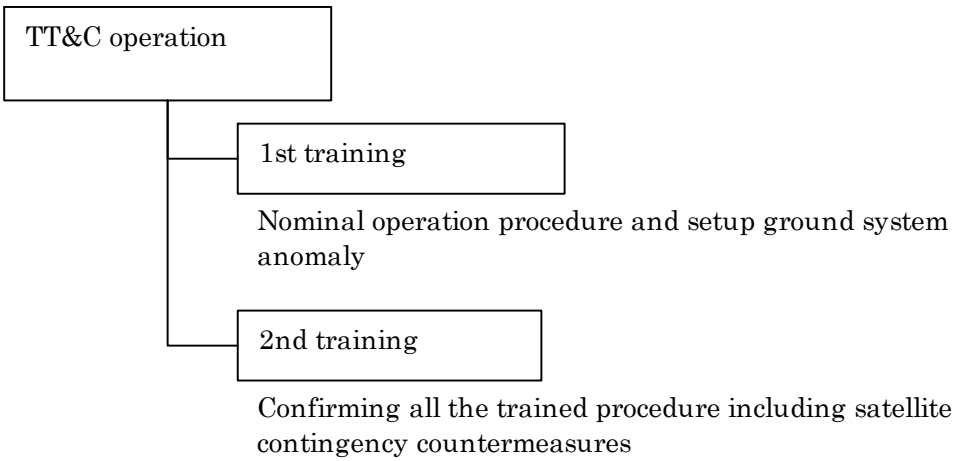

Figure 6. TT&C operation training Contents

The satellite setup anomaly should provide enough information to identify the cause of the anomaly. The anomaly scenario should consider the convergent point including the anomaly-response meeting. Without a clear convergent point, the practical training possibly becomes endless, which is not unreasonable due to the limited time and resources for the training. The setup anomalies are conducted throughout the entire shift of the TT&C operation training.

V. Evaluation

A. Total Training Day

The manpower costs of training have been reduced by over 50% with the implementation of this new method. Figure 7 compares the previous and current total training periods. The skill map allows unnecessary training to be avoided. Classroom training is mostly replaced with web-based self-training.

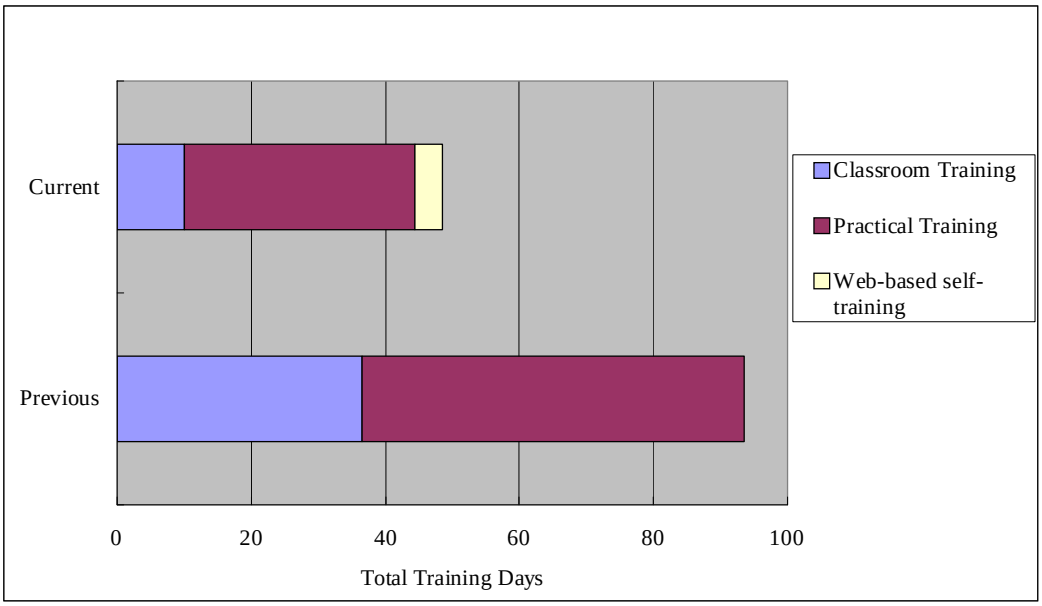

Figure 7. Comparison of Current & Previous Training Total Training Days

B. Web-based self-training

The web-based self-training contributed to the decrease in training time while providing more flexibility in training. On the other hand, the amount of time required to prepare the training material was increased. Preparing the contents of the web-based training is time consuming, so the number of students who will use it for a given training item should be considered when determining the web-based self-training contents.

The training can be done anywhere with online connectivity, providing great convenience and flexibility. The permission-based system restricts access to the learning material, also ensuring information security. Upon completion of the web-based self-training, participants demonstrated smooth transitions to the practical training. The web-based self-training amply proved that it provided the necessary skill and knowledge to the operators.

C. Practical Training

For the TT&C operation training, the satellite simulator is used to simulate telemetry and command operations. It contributes to increasing the depth of the operator's understanding of the operation. The satellite simulation data is not perfectly consistent real data in some cases, so the Training Control Board sometimes requires the distribution of such information as a special training matter.

VI. Conclusion

The new training methodology has been applied and refined over the course of three JAXA satellite projects. This training methodology has been successful in reducing the cost of training while also improving its quality. The major elements of this training are:

a A skill map that contributes to the removal of excessive training and successfully reduces the manpower cost by visualizing the training required skill and knowledge for each position.

b Web-based self-training that lowers the time investment and provides greater flexibility, more effectively training the operators.

c A satellite simulator that provides virtual TT&C operation training, which results in an increased internalization of the skills required by the operators.