Contributing to the SpaceWire international standard

—Successful factors for the development of a de jure standard—

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Incorporating standards for spacecraft in Japan involves trading off various existing standards to comply with requirements and sustainability. However, well-established proprietary specifications developed for Japanese scientific satellites were successfully incorporated into the international standard of embedded networks, called SpaceWire, which was adopted for the X-ray astronomical satellite "ASTRO-H (Hitomi)." Looking back on this proposal process, we studied a mutual collaboration scheme to incorporate Japan's proposal, regarding the development type international standards.

Keywords : De-jure standard, de-facto standard, SpaceWire, international standardization

1 Introduction

The onboard equipment installed in satellites is mutually connected by networks, and they transmit and receive commands and monitor signals called telemetry from each other. Standards for transmitting such signals are closely related to the ground stations that remotely control satellites and manage overall satellite systems. Since operating facilities of ground stations of various countries are used mutually, there is a growing demand for network communication standards to comply with international standards.

The process of introducing such international standards to Japan generally involves surveying several existing standards including for consumer products as well as spacecrafts, trading off with those standards, and selecting the specification that fulfills the required function and performance and for which continuity can be expected, after checking the background situation of standard establishment. On the other hand, in Japan, since proprietary development has been conducted for satellites used in scientific observations from the beginning, there are cases in which proprietary standards are being used.[1] For international standards, continuous revisions are conducted reflecting progress in technology, and this also involves revisions based on rapid technological advances in consumer product markets as well as establishment of new standards. While it should be possible to incorporate Japanese proprietary standards into international standards, this was not easy. This was not because of technological factors but because there seemed to be no motivation for proposing the Japanese proprietary standards as international standards for communication among the equipment onboard satellites.

The X-ray astronomy satellite "ASTRO-H (Hitomi)" dramatically improved functions and performances required for satellite systems compared with conventional Japanese satellites.[2]–[5] Development of equipment onboard ASTRO-H was conducted under wide-ranging international cooperation. Therefore, development that ensured continuation of the conventional development as well as compliance to international standard was required. The SpaceWire international standard[6][7] employed for ASTRO-H was a *de jure* standard that the European Space Agency (ESA) oversaw. We were able to incorporate proprietary standards that were formed with Japanese scientific satellites over the years into the international standard.

Looking back at the process by which Japanese proprietary standards were incorporated into the SpaceWire international standard and considering the success factors, it is possible to provide explanation based on the way of thinking presented in Reference [8]. The SpaceWire international standard was consolidated and established through discussions among the parties involved about the functions and performances to be realized, and its implementation method was set by specifying as international standards while technological development was conducted. This can be called a development-type standard.[9] In this article, we look back on the proposal activities based on the thoughts of Reference [8], and discuss the reproducible proposal process for the development-type international standard of which cases are increasing recently. Chapter 2 explains the route by which the system architecture of ASTRO-H, which is a compilation of SpaceWire standard products totally adopted for the first time, was recognized internationally. Chapter 3 summarizes the technological factors that allowed the Japanese proprietary technologies

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and proposals to be reflected in the international standard in the development process of ASTRO-H. Moreover, in looking back at the Japanese behavior pattern up to the moment the proprietary technologies and proposals were incorporated in the international standard, in Chapter 4, we compare this behavior with those of the American and European personnel referring to the model described in Reference [8] and consider the reproducible proposal process utilizing the Japanese behavior pattern.

2 System architecture of ASTRO-H

The development of ASTRO-H was conducted under international collaboration to realize an "open platform" described in Reference [10], as a situation Japan aims to realize in the future. This is a condition in which new ideas, technology, and people gather from around the world, and state-of-the-art added values are generated at a Japanese center of activity. It aims to make Japan the center for global intellectual activity. It also aims to create a structure to solve the problems that prevent the development of a spacecraft system that may produce innovative results, through cooperation transcending organizations. By lowering the threshold of joining the development of spacecraft systems, it provides opportunities for participation by a wide range of citizens.

As equipment installed in scientific satellites become diverse, the major issue is the difficulty of conducting development in a short time period while maintaining high reliability, as well as the complexity of the tests during the developmental process. Therefore, the R&D for spacecraft system architecture has advanced to conduct highly reliable design from the perspective of data handling and intercommunication among onboard equipment.[11][12] Scientific satellites involve a wide variety of mission purposes, such as near-earth or deep space observations. Since different forms have to be adopted, depending on their missions, one of the most important perspectives is to make a data handling system scalable for the architecture that can be used commonly in small and large satellites, rather than the concept of a fixed common bus. The network of electronic equipment installed onboard ASTRO-H that complies with the SpaceWire international standard was developed based on the "Future prospect of data handling system of scientific satellites" described in Reference [13]. The fully redundant[Note 1)] SpaceWire network that aimed for the SpaceWire international standard was realized for the first time in the world in ASTRO-H.[14] It was highly acclaimed in Europe where the standard was established, and ASTRO-H was introduced in the opening pages of the material published by ESA for the public, as shown in Fig. 1.[15]

3 Efforts by Japan

In developing the satellite onboard communication standard for ASTRO-H, approach was taken in which the personnel of Japan actively contacted the personnel of Europe and USA, conducted practical development and onboard demonstration from the planning stage of the standard. The team proposed improvement to the specifications that were derived through abundant achievement in Japan for the international standard. For the test and validation environment of the equipment that complied to the SpaceWire international standard, international joint R&D was done from the planning stage, and R&D and preparations were conducted to aim at unifying international understanding for handling the off-nominal[Note 2)] conditions that were not written in the specifications.[16]

It was the first time that a proposal from Japan was incorporated into the international standard for satellite onboard networks. The proposal from Japan was of a wide variety, from definitions of major protocol layers to fine correction of errors. In this chapter, we look back over the major three points that were incorporated into the standard, as well as the international joint R&D of the test and validation environment. These are culmination of

Fig. 1 SpaceWire international standard and ASTRO-H were presented in WELL CONNECTED, *European Space Agency Bulletin* (February 2011)[15]

experiences for the development of data handling systems such as scientific satellites, practical satellites, and space stations that have been developed by Japan.

3.1 Difference in viewpoint for optimal design

The Japanese proprietary specifications were utilized in the SpaceWire remote memory access protocol (SpaceWire RMAP), one of protocols in the SpaceWire international standard. RMAP is the protocol to read and write memories and others in the equipment connected to a network. Looking back at this process, it was found that there were two advantages to the Japanese development process.

One was the skill in obtaining consensus by smoothing communication among the organizations that carry out the R&D. In the communication standard layer that was initially being overseen by the SpaceWire Working Group Committee (SpW WG) that was set in the European Space Research and Technology Centre (ESTEC), a research institution of ESA, there was a layer added to realize real-time properties. It was called SpaceWire-RT or SpaceWire-T. In this proposal, the interface that directly linked to the uppermost telemetry command layer had a complex specification, and an agreement could not be reached for nearly a year because of heated discussions. From our experience of development and operation of the data handling system for Japanese scientific satellites, this protocol layer had a heavy implementation load and was not practical. Those of us participating in the SpW WG through the Japan Aerospace Exploration Agency / the Institute of Space and Astronautical Science (JAXA/ISAS) realized one point. Europe is a society that defines the content of one's job very precisely. The protocol layers of the communication standard had clear interfaces and could be easily divided into tasks, or enabled implementing specifications in parallel, and perhaps that was the reason there were overlaps in several portions in the layers. In contrast, the implementation the network protocol used in Japanese scientific satellites had the overlaps in each protocol layer skillfully removed. This indicates that the adjustment for each protocol layer was done adeptly under close communication among the parties involved when the specifications were compiled. We checked that RMAP itself was a protocol with sufficient function in providing real-time operation capability. Therefore, we pointed out that if we utilized this data format and communication protocol, SpaceWire-RT or SpaceWire-T were unnecessary in maintaining the real-time property, and imprinted our existing Japanese development specs in the form of an improvement proposal.[17] Moreover, Small Demonstration Satellite 1 (SDS-1) was launched in 2009, and the specification that we proposed was successfully demonstrated in orbit.

Figure 2 shows the communication standard layer that we proposed. We showed that what was initially done in eight layers or more could be done in seven layers, as shown in Fig. 2. The advantage of this communication standard layer is that it provides the real-time functionality required in onboard network for satellites by a simple protocol, based on the experience of development and operation of scientific satellites. The draft proposal was submitted at the 15th SpW WG in 2010 and obtained unanimous approval from the participating countries of ESA/ESTEC. This realized the simplification of the SpaceWire communication standard layers, and scalability could be realized from small satellites of 100 kg level to large satellites of 2.7 tons. We believe the simple and high-performance characteristic of SpaceWire could not have been obtained if this proposal was not submitted from Japan.

Another advantage is the point that we were able to respect the positions of the participants of all countries even in midst of the standardization proposal. As mentioned before, we swiftly launched SDS-1 in 2009 and succeeded in demonstrating the SpaceWire RMAP standard in orbit for the first time in the world. At this point, we felt for the first time that ESA trusted us. However, it was not because our technological level was demonstrated. They worried whether the standard on which they were working would be operational in orbit, or not. Instead of reporting that Japan was successful in onboard demonstration of the SpaceWire RMAP in orbit, we reported that the draft standard specification on which we were working that was the result of SpW WG was successfully demonstrated in orbit. In consequence, the results of the orbital demonstration by Japan wiped out their worries, and its success was shared by all parties involved. It seemed this led to the trusting relationship.

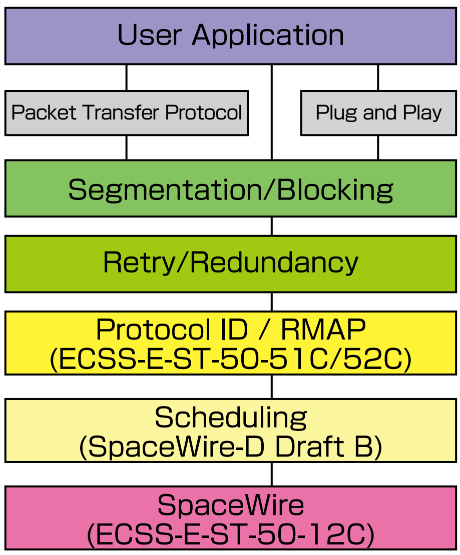

Fig. 2 Communication standard layer proposed to SpW WG from Japan[17]

3.2 Concurrent scheduling of time slot

The framework for maintaining sufficient real-time property on the SpaceWire network was greatly simplified based on the Japanese proposal mentioned earlier, and a design guideline was published as SpaceWire-D.[18] In the initial SpaceWire-D standard proposal, only one communication transaction per one time slot was allowed. This was based on the European claim that if multiple transactions were allowed in one time slot, the real-time property could not be verified, and the proposal was made as a standard of simple scheduling.

However, we have developed and operated a data handling system that enabled multiple transactions of communication within one time slot for many years, and had sufficient orbital experience. Although the practicality of this specification was empirical, JAXA knew the European culture that placed importance on formal and logical verification. Therefore, a government-academia-industry joint research plan was promoted, and through joint R&D by JAXA, Nagoya University, and the industries participating in the project, we created a guideline that could handle the European way of thinking in which importance was placed on the logical (formal) verification.[19] Based on this experience, we made proposals to implement multiple transactions of communication within one time slot, and this was reflected in the above specification as the concurrent scheduling of time slots. Here, the European claim that multiple communication transactions within one time slot could not be verified was reviewed, and specs were created as design guidelines to realize verifiable real-time performance. This was a result of the fusion of empirical knowledge that reflected the experience of the development and operation of the Japanese satellites, and the explicit knowledge of Europe that placed importance on logical integrity and verifiability.

3.3 Plug-and-play

The SpaceWire RMAP standard has several similarities to the specification of the peripheral interface module (PIM)[1] that had been conventionally used in Japanese scientific satellites as the communication standard. Based on the orbital operation experience in Japan, in ASTRO-H, the RMAP functions were utilized to define the address range that could be commonly referenced with the addressing mode called the standard RMAP address space that encompassed the common address space for the whole network. In this address range, when a certain address was accessed, the address and the communication service were linked so the data exchange (communication service) could be done with a communication protocol corresponding to that address. This feature was referenced at the SpW WG, and in the SpaceWire plug-and-play standard (current Network Discovery Protocol),[20] the specification was set so the standard RMAP address space set in ASTRO-H could be applied. As a result, the concept of "plug-and-play that links the satellite onboard equipment as if we plugged into an outlet" was realized.

Plug-and-play is a concept that is generally applied to consumer products, and in Japan, it was thought that the application to spacecraft onboard equipment was not very realistic. On the other hand, PIM that was Japan's proprietary standard was similar to the plug-and-play concept defined by Europe, and this led to the actual specification proposal.

3.4 Results of Japan-Europe joint development

ASTRO-H was developed with the goal of connecting each equipment "like plugging them into an outlet" so they could be immediately tested or operated. Therefore, a test and validation environment was prepared considering unit tests, procurement plans, and subsystem tests, not only the development of equipment and subsystems. Moreover, expecting that the development would be conducted under wide-ranging international cooperation, the joint R&D for the RMAP conformance tester was conducted jointly with the University of Dundee that was overseeing the specifications for SpaceWire subcontracted by ESA.[16] This allowed the development of test specifications and pass-fail determination including responses under off-nominal conditions that are not clearly written in the specifications to be conducted in Japan. The devices that were developed in various countries were brought to Japan, and this allowed thorough development of a full redundancy network for large 2.7-ton satellites.

In the RMAP conformance tester, there were about 80 % of off-nominal test cases that were mutually understood and extracted in the process of the Japan-UK joint R&D. The off-nominal test conditions are not clearly written in the standard specification. However, careful investigation of off-nominal test conditions not only enables exact test and validation, but also detects insufficiencies and defects in the setting of nominal test conditions. As a result of such steady R&D, the RMAP standard which matched the understanding and requests of the personnel of Japan and UK (and Europe) was established. The RMAP conformance tester is used around the world as a *de facto* standard, and this includes both cases of nominal and off-nominal test. As a result, both the nominal and off-nominal conditions were guaranteed to have conformity and understanding, and if Japan purchased overseas equipment that complied with the SpaceWire international standard, they could be installed onboard the Japanese satellite system. For the tester for SpaceWire, joint development is being conducted with other European companies, and continuous cooperation is pursued to maintain conformity and international understanding.

4 Comparison of behavior patterns of each country

In the previous chapter, we summarized the technological elements in the Japanese proposals that were reflected in the SpaceWire international standard and reviewed the standard proposal activities. To extract the success factors that enabled the Japanese proposals to be reflected in the international standard, we shall look at the behavior patterns of the Japanese participants, not just the technological accomplishments. In this chapter, the basic loop for a specific subject to evolve continuously, as explained in Reference [8], will be used as a model for the discussion.

4.1 Reference model

The basic loop referenced in this article is shown in Fig. 3.[8] The blocks shown in the figure are autonomous entities that include humans (individuals, organizations, society), and there is no integrator that controls the whole. The condition of the subject is observed by the observer, and the observer sends out an alert as it interprets the meaning of change in status. The configurator thinks and gives advice on the action that should be taken when the alert is sounded. The actor voluntarily selects the advice, and acts based on such advice. The behavior assimilates with the subject and changes the condition of the subject. When the change is observed again, the information circles along the loop. As a result, the subject evolves. As it can be seen, interpretation, conception, selection, and assimilation are done autonomously rather than heteronomously, and this means that each block is a self-governing or autonomous entity, and this is thought to be the condition of evolution.[8]

In fitting the SpaceWire international standard to this basic loop for consideration, the condition is that each block is an autonomous entity. Specifically, SpW WG corresponds to the observer, and the European Cooperation for Space Standardization (ECSS) that is called the Technical Committee (TC) corresponds to the configurator. The vendors of the industrial world correspond to the actor, and the subject is the onboard satellite device or the communication standard for data that are exchanged among the equipment. Although the SpaceWire international standard is the *de jure* standard set by Europe, the SpW WG is placed in the preliminary stage of the TC that establishes the international standard, and it

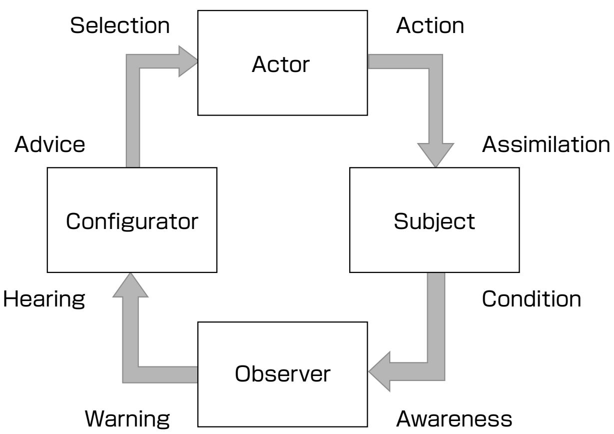

Fig. 3 Basic loop required for continuous evolution of a certain subject[8]

is accepted that the participants to this WG are autonomous beings. The participants can give individual opinions, and the vendors who are also actors can participate in the WG. They do not have to be representatives of national space agencies. This is different from the standard establishment process by country representatives that was the general practice for conventional communication standard establishment for spacecraft onboard equipment. It is a case of development-type standardization of which cases are increasing recently.[9] Moreover, the European vendors are allowed to participate in the ECSS which is the configurator. In the following sections, the Japanese behavioral pattern in the SpW WG is fit into the basic loop and is compared with European and American behavioral patterns. In this discussion, a member of each block may overlap, and the arrows represent the roles of how they approach each other.

4.2 Behavioral pattern of European participants

The observer-configurator and the actor are separated and there is a division of labor. The observer-configurator is a governmental organization represented by ESA and may include system and equipment vendors. The actor is often a hardware or software vendor, and in some cases equipment development divisions of system vendors may be included. The division of labor between the former and latter groups is clearly separated in the specifications, and while there are frequent information exchanges such as conversations among the two groups, it is not common to see a case in which the work overlaps. That is, the work of investigating the specifications, and the work of manufacturing equipment to which the specification is applied almost never overlap. The actor waits for the specs and order from the observer-configurator, and the observer-configurator waits for the results of the actor to be reflected in the subject.

This behavior pattern will be explained by separating the observer's place and configurator's place, as well as the observer and the configurator in the basic loop shown in Fig. 3. A member participating in a certain place becomes clearly aware of the role allotted to the place, the source from which information needed for decision-making is obtained, and the place to which the contents of the discussions are to be transmitted. In establishing the SpaceWire standard, the observer's and configurator's places are designated, and research institutes, universities, and companies are able to participate in these places. For the observer's place, participation from outside Europe is not denied, and in some cases, such participation is encouraged. The observer and configurator may overlap, but when discussions are done in the observer's place, one must be aware that one's standpoint is about observation of the subject. When discussions are done in the configurator's place, the reports from the observer's place are received as formal reports, while the reports from the actor are not used directly for decision-making. The person who is an actor may participate in the SpW WG that is an observer's place and may give his opinions, but the actor does not engage in activities such as prototype making when it is in the observer's place. That is, it seems that the authority in establishing international standards is controlled by gathering and limiting the configurator's input to the observer's output. The aforementioned TC corresponds to the configurator's place, and only those selected within Europe can participate. Here, the observer's reports and standard proposals are screened. The observer's place has the authority to propose but does not have the authority to establish the standard. The authority to establish the standard is held by the TC or the configurator's place. This is shown in Fig. 4. In Fig. 4, the members are shown in rectangular boxes with sharp corners, while the places are shown as rectangles with rounded corners.

The reason why the observer's and configurator's places are separated is because the standard proposals are compiled after conducting adjustments within Europe. Manufacturing and specification settings are structurally separated, and the participants of the observer's and configurator's places have low awareness of being the actors. For example, in cases in which personnel from industrial vendors take roles of the observer or the configurator, it often happens that they must move to other organizations.

4.3 Behavioral pattern of participants from USA

There is no clear hierarchical awareness for the observer, the configurator, and the actor among the participants from the USA. The observer acts on the subject as the actor and expects quick feedback. Also, they expect the SpW WG, which was originally set up to be in the observer's place, to have the mindset of the configurator, and to directly make standard proposals. That is, they are not aware of the limitations of the observer's place. While the authority and the role of the TC as being in the configurator's place are recognized, they think it is possible for the actor to directly propose in establishing standards at the configurator's place. They propose specs gathered through the actor's performance in the market to be used as international standard specifications, and therefore, expect discussions on considering them as *de facto* standards. This means that the information between the actor and the configurator flows in both directions. This is shown in Fig. 5. The bidirectional arrow between the actor and the configurator, as shown in this figure, does not match the behavior pattern of the European participants in Fig. 4. That is, this model shows that the behavior pattern of American participants is not accepted in Europe.

While the hierarchy of the observer, the configurator, and the actor not being separated is similar to the Japanese behavior pattern, it is not uncommon that the observer and the configurator share common interests as actors. In such cases, the Japanese participants tend not to be able to compete, but the Europeans consider the WG Committee as the observer's place, and here, the proposal of specs based on existing performances as international standards or as the *de facto* standard is not accepted. For the Japanese participants, it can be thought that this is an opportunity given to objectively state their opinion.

4.4 Behavior pattern of Japanese participants

Japan has a setup of establishing Japanese standards through the supervision of JAXA. In the establishment of the SpaceWire standard, there is no clear division of labor as in the European example of SpW WG that corresponds to the observer's place or the ECSS that corresponds to the configurator's place. Instead, a design standard working group is set up as the configurator's place for standard establishment. The configurator's place has a high degree of independence, and there is no structure in which the observer definitively acts on the configurator as seen in the European example. Members from the national research institutions,

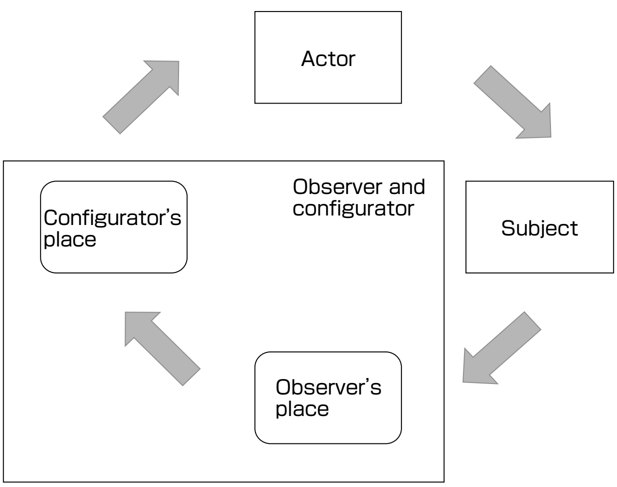

Fig. 4 Behavior pattern of European participants

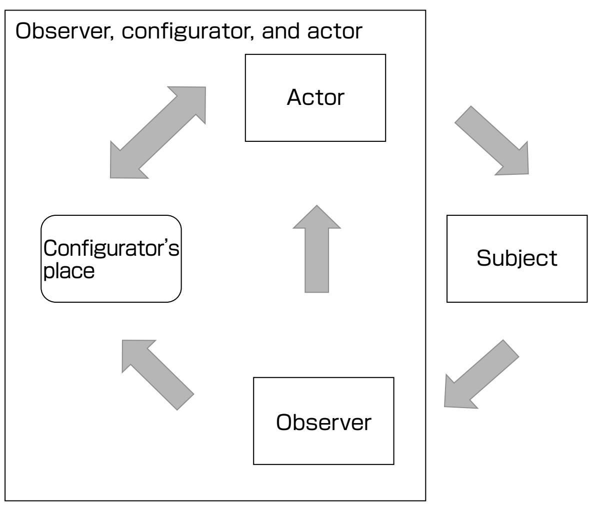

Fig. 5 Behavior pattern of American participants

universities, and companies participate in the design standard WG that is a configurator's place to establish the standard. The members in universities and research institutes often act as observers in the standard establishment process, and may become actors during the R&D. Also, the manufacturing companies that normally act as actors may become observers as system vendors. This is thought to be due to the background that the Japanese space development has been conducted jointly by government and private companies. In this case, it is possible to incorporate output from an overseas configurator's place, and it is also possible to quickly realize international standards in products. This is shown in Fig. 6(a). It is not uncommon that the observer places an order to the vendor who is the actor based on proprietary specifications, without consulting the configurator. In such cases, the subcontract specifications correspond to the arrow that points from the observer to the actor, but the content of subcontract specifications in many cases is based on the mutual interaction between the actor and the observer, and the arrow should go in both directions. Only after accumulation of experiences, the standard is established formally at the configurator's place, and its promotion is done by the actor. The configuration shown in Fig. 6(a) has no arrows of influence that conflicts with the European behavior pattern and can be superimposed well. This is shown in Fig. 6(b).

The SpW WG, as mentioned above, accepts participants of those who stayed outside Europe to the observer's place, and has the mechanism of unitarily incorporating the output of the observers' place into the configurators' place. The Japanese participants participated in the observer's place with the consciousness of both the observer and the actor. This consciousness did not cause conflict in the Working Group Committees. This was in contrast with the conflict between the American and European participants generated by the American way of thinking of bidirectional awareness in the observer's and configurator's places.

The participants from Japan had a unified way of thinking of the actor and the observer, and the example of SDS-1 mentioned earlier shows that the Japanese behavior pattern shown in Fig. 6 fits well with the European behavior pattern shown in Fig. 4. The results of the American preceding development could be brought into the configurator's place without stress through the Japanese proposals, and it is thought that this contributed to bridging the gap between the USA and Europe.

On the other hand, issues Japan faced became apparent. For the technological investigations discussed in the SpW WG, there were not any apparent differences in terms of the technology level between USA's National Aeronautics and Space Administration (NASA), Europe's ESA, and Japan. However, Europe and USA had many orbital demonstrations of new technologies and plenty of examples of new equipment being used. What is the cause of this difference? The participants of the SpW WG included about 14 countries from Europe, USA, the Far East, and Asia. The countries engaged in their original development, and some are leading in demonstrations of new technology. The performances were referenced to determine specifications to be aimed at. Risks of practical utilization were indicated from various perspectives. Even if the problem was pointed out, alternative plans were proposed actively. The claims and proposals of Japan were adopted without discrimination if they were reasonable, backed by experience, and matched the direction of SpW WG. The fact that there was a place for gathering

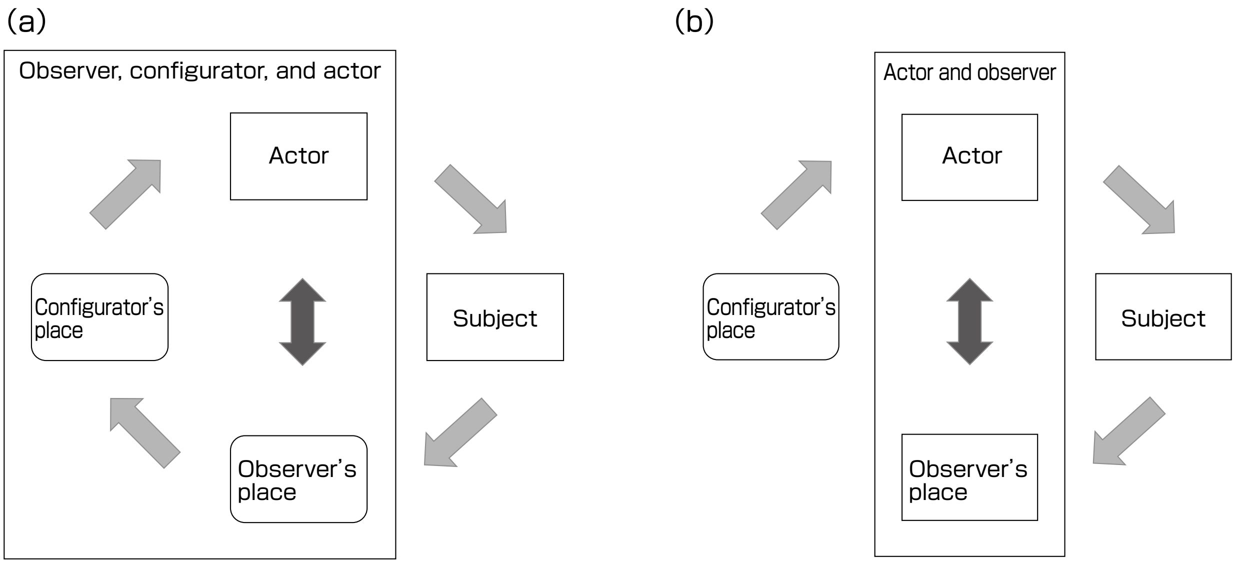

Fig. 6 Behavior pattern of Japanese participants
(a) Domestic standard establishment process; (b) combination with European *de jure* standard establishment process.

and listening to specialists with various backgrounds led to innovation, cost reduction, downsizing, and weight reduction, and as a result, linked to the "precedents of Europe and USA." That is, there is a need for a platform to be prepared to gather skills and knowledge of the participants who have diverse backgrounds toward a common goal. The issue was to prepare such a platform in Japan.

5 Summary

In this article, we reviewed the process by which the Japanese proposals were reflected in the SpaceWire international standard, and the success factors were considered referring to the conceptual model for continuous evolution of the subject described in Reference [8]. In looking back, we were able to reconfirm that the Japanese proprietary technologies were valid internationally, and the Japanese behavior pattern of respecting the preceding technology while conducting "kaizen" was effective in incorporating (the word "rub in" perhaps better describes the situation) the proprietary technology into international standards. As a result, we believe we were able to describe the empirical knowledge for reflecting the Japanese proposal in an international standard utilizing the European *de jure* standard establishment process as a reproducible model. By being aware of this model, we hope the activities for getting the Japanese proposals reflected in international standards will be activated.

6 Acknowledgement

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Note 1) All onboard units have redundant systems.
Note 2) It is not the normal condition that is set in the specifications.

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Discussions with Reviewers

1 Overall

Comment (Akira Ono and Motoyuki Akamatsu, AIST)

For the international standardization of SpaceWire that is the communication standard for onboard satellite networks, the scenario by which the Japanese proposal was adopted is described from the technological background and the roles of people involved. The Yoshikawa model was applied for the development-type standard establishment, and analysis is done for the behavior patterns of European, American, and Japanese practitioners of standard establishment. This process can generally be applied to any standard development, not limited to the satellite communication standard, and therefore this article is appropriate for publication in *Synthesiology.*

2 Range and role of the participants in standard establishment

Question (Akira Ono)

So-called international standards include ISO and IEC, and the international standards are created by agreement among the standardization institutions of various countries. For the SpaceWire international standard, the main subject of this article, what kind of people and organizations were involved and agreed to create this international standard? I imagine that the space technology specialists from around the world, space agencies of various countries, ESA, and others were involved, but which entities played what roles in creating the SpaceWire international standard?

Answer (Hiroki Hihara)

SpaceWire was originally proposed by the European Space Agency/European Space Research and Technology Centre (ESA/ESTEC). It started this investigation with the objective of creating a standard for inter-device communication onboard spacecraft without using special parts for military use that were conventionally used in spacecraft. International standards are established within ESA by the Technical Committee (TC) that is part of ESTEC. However, prior to the establishing process at the TC, the SpaceWire Working Group Committee (SpW WG) was set up to take the role of discussing specifications and then submitting the specs to the TC.

There is no restriction to the qualifications to participate in the SpW WG. People of any country, regardless of whether they belong to government, academia, or industry can participate.

There is no restriction to the right to speak in the SpW WG, and anyone can speak freely. In fact, space agencies, universities, and companies of Europe, Japan, Russia, and USA are participating, and space-related government organizations and research institutes of Turkey, Brazil, and others participate occasionally.

However, I do feel that there is a tacit understanding about whom Europe will accept as participants. That is, although there is no clear qualification, only those who are capable of actually conducting spacecraft R&D and are able to propose and discuss specifications are accepted as participants.

3 Development-type standard

Question (Akira Ono)

You use the terminology "development-type standard," but how is this different from ordinary standards, and what is its definition? Please explain why the SpaceWire international standard is a "development type." Also, if something is a development-type international standard, what is the author's thoughts on the points that must be considered in such standardization compared to conventional standards?

Answer (Hiroki Hihara)

The terminology, "development-type standard," is taken from Reference [9]. It was cited from Masami Tanaka's *Kokusai Hyojun No Kangaekata—Global Jidai He No Atarashii Shishin* (Dialogues on International Standards—A Guide to the Global Age) (University of Tokyo Press, 2017). I understood the terminology, "development type," as a situation where there is a preceding objective for development, and the discussions begin from the standard system that is necessary for achieving the objectives and the types of standards. Organizations that participate in the SpW WG are expected to present the results of their R&D, prototype evaluation, and orbital demonstrations which they conducted. Moreover, all presentations are respected. I think those situations can be expressed by the term, "development type."

In conducting the standardization proposal, although the SpaceWire itself is a communication standard, there were recommendations for connectors and semiconductor devices, there was tolerance for introducing new technology while guaranteeing the reliability required for spacecraft, and the SpW WG participants were expected to pursue advanced functionality and performances. I felt this led to tacit understanding, and this is the point to which one must pay attention.

Also, there was reorganization of the range to which the standard applied, and the scheduling of standard establishment was unclear. The companies must be able to continue product development and make proposals by actively disclosing the parts where compatibility with other organizations was necessary in their product specs. The ability to make proposals even under an uncertain schedule is another point to note.

4 Organizations that correspond to observer, configurator, and actor

Question (Akira Ono)

Please explain which organizations correspond to the "observer," "configurator," and "actor" that you mention in "Chapter 4 Comparison of behavior patterns of each country" when the case is applied to Japan. Is my understanding that follows correct: "subject" = satellite or onboard sensor and/or data and information obtained from them; "observer" = research institution, university, researchers of JAXA, and/or data users; "configurator" = JAXA; and "actor" = manufacturing companies? Does such corresponding relationship apply to overseas organizations?

Normally, a standard is considered to be an agreement to which product providers and users are expected to comply in carrying out commercial trade, but in this article, to which entities do the product providers and users correspond?

Answer (Hiroki Hihara)

In Japan, there is a mechanism for domestic standard establishment that is overseen by JAXA, and the standard is established based on the discussions between the manufacturing companies which are the actors and JAXA which is the observer, concerning the satellite and observation data that are the subject.

The universities and national research institutions often take the standpoint of observers in the standard establishment process, and take the standpoint of actors in R&D. Also, the manufacturing companies with the characteristic of system vendors may participate in standard establishment with the perspective of observers. Since standard establishment is done by the standardization committee consisting of participants that share a neutral position that keeps them independent from their respective organizations, the configurator's place has high independence, and I think this is related to the background that the technological development of spacecraft in Japan was conducted through cooperation between public and private sectors.

In cases of overseas countries, Europe does not interfere with the research institutions which they are not space agencies, as long as it is for the SpaceWire standard. I do have an impression that there is a clear division of role among the research institutions according to their standing. In the USA, universities are not involved in standard establishment, and only NASA and the companies are involved. Therefore, both Europe and USA have different response to the reference model compared to Japan.

In the model referenced in the article, I think the aforementioned difference can be expressed by referring to the provider and the user as the actor and the observer. However, in the case of Europe, there is a way of thinking that the standard can be used as part of the structure of commercial trade, and I think the observer can take the standpoint of the configurator and become the provider of the structure of trade.

5 Cause of difference of behavior pattern of each country

Question (Akira Ono)

In Chapter 4, you explain the differences of the behavior patterns of Europe, USA, and Japan. What do you think is the main reason there are different behavior patterns among the countries?

Answer (Hiroki Hihara)

Through experiencing the process of SpaceWire standard establishment, I think the main reason that generates the difference in behavior pattern is the difference of policy for nurturing industry. Europe aims for coexistence that does not favor elimination and avoids the risk of stagnating progress by reaching an agreement through discussion that allows the presence of different values. USA consciously accepts elimination and promotes progress through selection of proposals. Japan seems to position standards as mediation means rather than a way for nurturing industry.

6 Issues for Japan

Question (Akira Ono)

Compared to Europe and USA, what do you think is the issue for Japan in terms of behavior pattern?

Answer (Hiroki Hihara)

Compared to Europe and USA, I feel that there is no place to make use of diversity in Japan. In Europe, common sense based on tacit understanding seems to exist in each European country, and there is a place for discussion while respecting the differences in values and experiences of different countries, and this is useful in explicitly utilizing diversity.

USA has diversity within itself, and it is conscious that achievement can be attained through different viewpoints and is clearly aware that diversity is the source of their strength. Japan has diversity within its country, but I feel there is no place to share the achievements that arise through diversity.

Question (Motoyuki Akamatsu)

You explain that it was not easy to incorporate the Japanese proprietary standard into the international standard, but please explain why it was not easy.

Answer (Hiroki Hihara)

On the point that you indicated, I think the main reason was motivation, and I added this in the text.

7 Joint research with universities and standardization

Question (Motoyuki Akamatsu)

You write about the concurrent schedule, and I understood that the point here is that you constructed the design guideline through joint research in addition to the orbital demonstration. Was this joint research part of the scenario that aimed to take this to international standardization? If so, based on what decision was this joint research conducted?

Answer (Hiroki Hihara)

Looking back over the joint research, I think Professor Takahashi, who was the project manager of “Hitomi” project, was knowledgeable about the European culture that placed emphasis on formal and logical verification. I am now aware that he worked on the government-industry-academia joint research plan to prepare the specifications based on empirical knowledge into a form that was acceptable in Europe, and in this joint R&D, he constructed the guideline that made possible the scrutiny of European way of thinking that placed importance on logical (formal) verification. I added this point to the text.

8 Future contribution

Question (Akira Ono)

This article describes a case in which Japan contributed greatly to the creation of an international standard for space technology. What is the most important point if Japan wishes to continue such contribution in the future? It can be on general technology other than space technology.

Answer (Hiroki Hihara)

Looking back at the process of SpaceWire standard establishment, I think the most important thing in the future is the will to work not only on preceding examples but also on diversity. There are two reasons for this as follows.

First, with the thought of so-called “kaizen,” rather than the mind of competition that starts by negating the existing results, it was found that we could contribute to the establishment of international standard by respecting the existing results. This originates from the fact that the PDCA cycle can be turned quickly because we have a culture of unity where there is no hierarchy between the side that establishes the specs and the side that uses the specs.

Next, the kaizen method starts from the fact that there is a preceding case. With the improvement of the technological level in Japan, it has become difficult to find a precedent. In the future, we can keep the preceding cases in view by eliminating the idea of advanced versus developing countries, or new versus old technologies, and changing the awareness to capturing the precedents through expression of diversity.

From these reasons, diversity should be considered as precedents, should be respected, and should have kaizen applied. Then we can coexist with the values of competition of Europe and USA and shall be able to continuously contribute to international standard establishment.