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The requirements for continuous innovation in advanced large-scale technology development - Case study of supercomputer development -

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Advanced technology development, especially large-scale development, creates many innovations and has wide influence on many technology areas. So, the advanced large-scale technology development is very important for society and its economy. And to make innovation continuously occur is very important for the future of technology. This research analyzes the required conditions for such innovation to occur, taking supercomputer development as a case of large-scale technology development.

In the case of supercomputer, its performance has been improved continuously for more than 20 years, which is much beyond the usual technical trend. This implies radical innovation has been achieved successively. Thus the major research question (MRQ) is set as: “What is the requirements for continuous innovation in advanced large-scale technology development?”

To obtain the answer for the MRQ, three subsidiary research questions (SRQs) are set as: (SRQ1) What kind of innovation has occurred in the supercomputer development? (SRQ2) What is the cause of the innovation?, and (SRQ3) What is the reason of innovation to be generated continuously?

Abernathy & Utterback (1978) showed the dynamic model of the innovation which

detailed three phases of innovation where “dominant design” is produced in the second phase named “transitional phase.” Upon discontinuous technology emerged, it starts from the first phase of “fluid phase”, through a transitional phase to the specific phase, progressing as incremental innovation. Chesbrough (1999) has indicated that in order to produce a radical innovation, there is a limit in “closed innovation” in a company, in which case “open innovation” conducted in collaboration with outside companies is effective. Von Hippel (1988, 2005) has pointed out that the creator of innovation is not only makers but also users. The role of “lead user” is important for innovation emergence. The lead-user has a problem to solve especially in their advanced technology field and is ahead of the majority of the users with respect of the market trend. Thus the innovations developed by lead-users tend to have more attractiveness commercially. Innovation management tools like the innovation architecture (Tschirky, 2006) and technology roadmapping (Phaal, 2004) are available for companies.

Top500 supercomputer site is the supercomputer performance ranking web site, which has the data for the past 19 years of performance results based on Linpack benchmark program. The data there also have the information on who made supercomputers and who were the users of them. Total of six supercomputer manufacturers, with three companies for Japan and the U.S each, were selected to be compared for the performance they achieved with their high-end supercomputers for a long period of time. Selected companies were FUJITSU, Hitachi, and NEC from Japan, and IBM, CRAY, and SGI from the US. By visualizing the data of the products of each maker, it was analyzed what kind of innovation has actually occurred on supercomputer development. It was found that existence of the consecutive "radical innovation products" contributed to realizing the long-term performance trend of very high Top500. Radical innovations are critical for the industry to keep growing. For each radical product, the development process was analyzed based on literatures etc. as in detail as possible, and it was pointed out what kind of factors were related to the innovation. As for where the radical innovation came from, it was analyzed that paying attention to the external environment, development environment in the company, and market, is critical.

The external environment includes cooperation between industry and academia, and relation with users and other companies. Development environment means the technical base in the company such as R&D center, other products and related internal technologies within the company. Market factors include lead users who made innovation in collaboration with a maker and bought products in their early phase. Attentions were also paid to the national programs to develop supercomputers with focuses on participant and related companies. Moreover, the factors for achieving continuous radical innovations were investigated for the

Top500 as a whole.

From the result of the data analysis of Top500 with detailed analysis of a development process, the dominant designs which survived for a long period of time were not found to be existing in the supercomputer development. It was also found that, at the starting point, the radical innovations were created based on open innovation mechanisms, such as the industry-academia-government collaboration, M&A, and cooperation with other companies. The radical innovation occurred only once for one product line with respect to system architecture. And radical innovations were found to happen when the radical lead users were involved in the development phase such as in the national programs. It was also confirmed that innovation management in a company contributes to successful development in a closed innovation environment, examples of which include stretched development targets, listening to lead users who have deep influence on the company with respect to system specification requirements. Such radical lead users were found to be related to the national programs, which implies the importance of the national program to strengthen the industry by way of advancing science & technology capabilities of the related companies. In supercomputer industry, user innovation by the radical lead users is required for the radical innovation to happen. Moreover, the validity of the innovation management which is applied in a closed innovation environment in the company in the preparation and early phase in combination with a following open innovation mechanism with users of outside company plays an important role for innovation to happen effectively.

In conclusion, to achieve successful large-scale technology development, it is important to carry out open innovation policy in respect to let radical lead users involved as well as closed innovation policy of strengthening technology base continuously. With this environment, (1) setting stretched goal, (2) identifying radical lead users in the advanced market and (3) listening to and making best use of requirements of such lead users, are key factors for the development to be successful. Such innovations can be effectively managed by introducing management tools such as roadmapping and innovation architecture, which can make successive innovations be created.