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The Direction of Embedded Software Development: Focusing on Japan's Social Characteristics
—Reinforcing the basis for software development in electronics-driven durable goods—

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1 Introduction

From the viewpoint of strengthening a common foundation to gain higher industrial competitiveness, the 4th Japan's Science and Technology Basic Plan discussed issues surrounding the measures to cope with ever-diversifying market needs.[1] It sets out upgrading development technology of embedded systems, as well as other objectives such as integration of element technologies and the R&D for linking hardware and software.

To achieve sustainable growth, every advanced country inarguably needs to strengthen its internationally competitive industrial sectors. Among these countries, Japan is characterized by the fact that her visible trade balance heavily depends on the secondary industries. This trend, however, is undergoing drastic changes: the white paper on the economy and public finance for FY2011 gives a detailed discussion on the circular relationship among globalization, productivity, and research and development, wherein the paper places stress on the mounting importance of non-physical assets under the global knowledge-based economy environment.[2] Software is one type of typical non-physical assets, and as such, this sector is required to cope proactively with the promising global market, and to move towards the creation of new added value.

Japan's manufacturing sector, however, has already been exposed to fierce competition with the developing countries in East Asia. We must note that the improved technical capability in developing countries is the engine for their upgraded competitiveness, supported by lower production costs and their distinctive market capturing strategy. Typical industrial sectors that find themselves in such situation include those producing home electric appliances and automobiles (hereinafter simply referred to as durable goods). Ever increasing use of advanced electronics in these products in recent years – typically reflected in abundant use of embedded computers – has effected a change in the constitution of development cost in the products; the cost for embedded software development is surging its proportion in the total development expenditures. East Asian countries have also gained increasing capabilities in this area of development efforts, threatening the superiority of Japan.

Against the backdrop of these situations, this report discusses the development methods of software embedded in electronics-intensive durable goods, as one of the objectives conducive to strengthening a common basis for increased industrial competitiveness. It presents discussion on the objectives toward which we should focus our strengthening efforts, paying attention to some of the aspects in the social characteristics of Japan and how to leverage these for achieving our goal.

2 Embedded Software

2-1 What is embedded software

A general-purpose computer, typically PCs, can perform a variety of functions depending on the application program running on it. For example, a PC can be used for a variety of purposes including electric mail transmission, Web browsing, word processing, and scientific computation. The types of tasks it performs are determined solely by the application program running on it. In contrast, embedded computers are application-specific devices used, for example, to control engines and implement mobile communications. They constitute an integral part of automobiles, mobile phones, household appliances, and industrial equipment. The embedded computer, as it is a type of computer, also needs software to run on it – namely, embedded software.

Embedded computers are employed in a variety of equipment and apparatuses, from high-end devices that require the highest level of performance – space, defense, and communication sectors – to commercial-off-the-shelf products for general consumers (Table 1). Availability at low cost is rigorously pursued in the mass produced general consumer-oriented products, while reliability is of utmost importance for the specific-user oriented products. Reliability in the extreme is of critical importance for some of the high performance and large-scale equipment.

The trend in recent years shows prolific use of embedded computers in an increasingly wider area of products, and the number of embedded computers incorporated in one product is also increasing. The automobile exemplifies this trend: a modern automobile has many - several tens to in excess of one hundred – computers on board not only for engine control but also for such various applications including: air conditioning, air bag control, ABS (Anti-lock Braking System), power windows, car navigation, and audio systems (Figure 1).

2-2 Requirements for embedded software

The embedded computer is required, as a part of a product, to work smoothly in synchronization with other parts. It must meet the following requirements.

(1) Real time capability

Real time capability means that each required process must be completed in a given time. A PC takes some length of time for starting up, and processing time may be obscure: these are some of the properties that are taken for granted. The majority of embedded computers, on the other hand, must boot up immediately in sync with the system's power on, and its processing time is much more rigorously stated. Control equipments, in many situations, must respond to requests from the external world frequently, and often times these requests arrive simultaneously. In such situations, the embedded software must ensure the real-time nature of the equipment by completing the task without any delay.

(2) High reliability and safety

As exemplified by the brake control on board an automobile, some of the embedded computer controlled products are directly linked to the safety of human lives. On the other hand, some must assume use under harsh operating conditions such as severe vibration, under the scorching sun, and in intense cold. Some must handle multiple sensor signals coming

Table 1 : Examples of embedded computer driven device

	Specific user oriented (Low-volume production)	General user oriented (High-volume production)
High performance, large scale	・Communication infrastructure ・Satellite	・Mobile phone ・Automobile
Low performance, small scale	・Lighting control of structures ・Measurement instrument	・Washing machine, refregerator ・PC, peripheral device

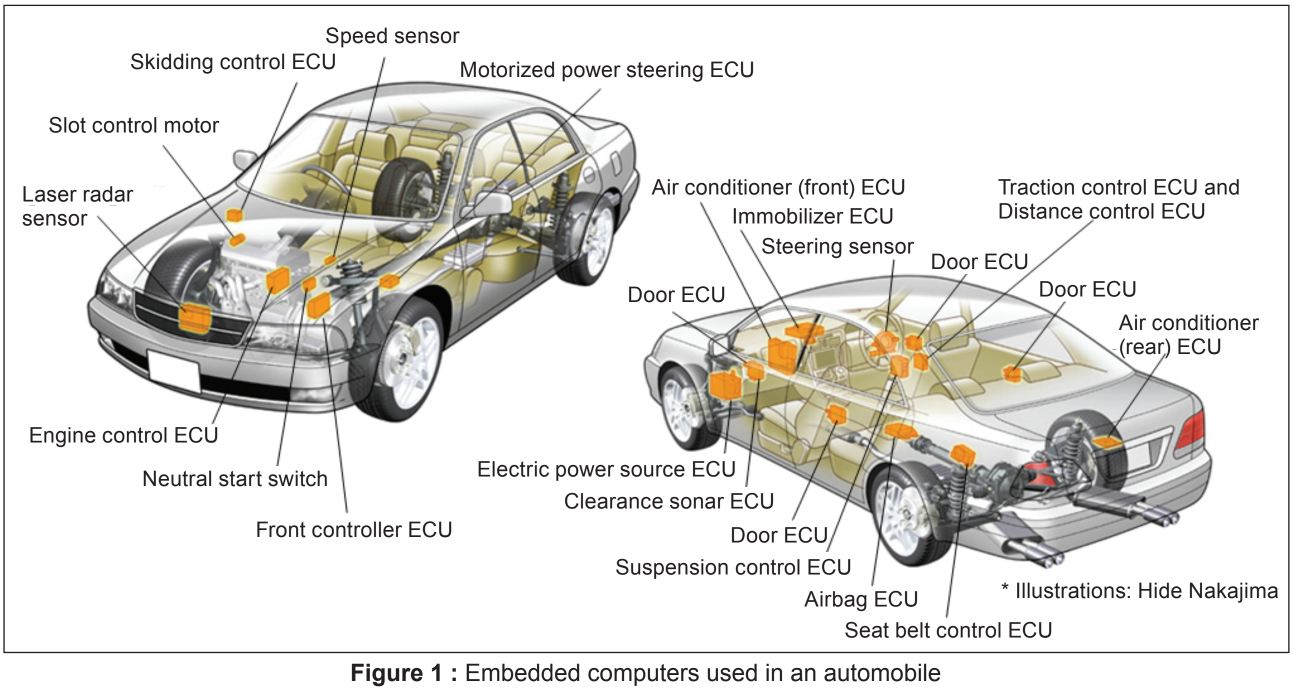

Figure 1 : Embedded computers used in an automobile

in randomly, and even go through unexpected usage caused by the operator's erroneous operations. A PC placed in such a situation may freeze up and come into a halt, but booting it again by electric power is a tolerated rescue practice for a PC. In contrast to this, embedded computers implemented in such devices as an automobile are required to maintain the highest level of reliability and safety at all time, enduring all input conditions and operating situations.

(3) Severely restricted resources for development

Some of the products that harness embedded computers, such as mobile phones, are subject to severe limitations on their physical size. High-volume products for the general users often have to highly compromise their internal specifications as a cost-cutting measure. These situations may force the products to abandon implementing sufficient resources, typically memory size, and the development efforts of embedded software also have to assume severe resource restrictions.

(4) High perfection level

General-purpose computers, suc as PCs, have most of their software on external storage devices (e.g. HDD) and load it into memory on an as-needed basis. This allows upgrading of the software by simply replacing it on the external storage device. Embedded software, on the other hand, is implemented in ROMs (Read Only Memory) during manufacture, almost eliminating the possibility of replacement/modification/deletion by the user.[4] Therefore, a high level of perfection must be achieved in the development phase on the understanding that there will be no maintenance by the user.

3 Current Status and Challenges of Embedded Software Development in Japan

3-1 Scale of development cost

Although embedded software is implemented in a multitude of products, this sector has not long been recognized as an individual industrial sector, due mainly to the fact that embedded computer, constitute a component of integrated combination. It was as late as in 2007 that the sector was added to Japan Standard Industry Classification (JSIC).[5]

The expenditure for developing embedded software surpassed even the level of ¥4 trillion in several recent years, and has shown by and large an upward trend in subsequent years. This is not a negligible amount in view of the total sales amount of Japan's software sector (¥15.6 trillion: June 2009). The cost ratio of embedded software development over the total development budget is also increasing: it occupies more than 40% of total development cost.[4, 7] (Figure 2)

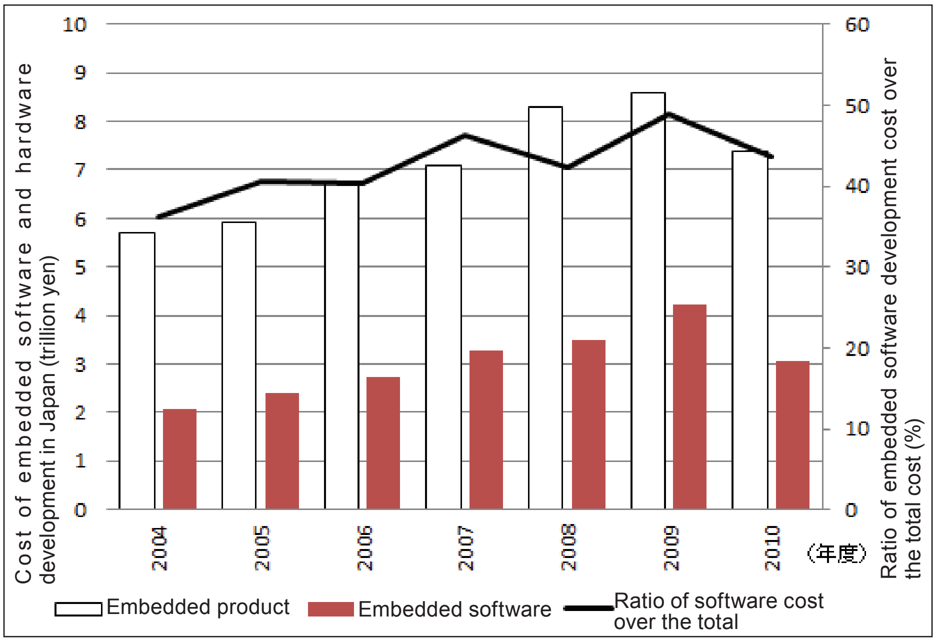

Figure 2 : Trends of development cost: embedded software controlled hardware (embedded product) vs. embedded software

Prepared by the STFC based on Reference[8]

3-2 Changing situations surrounding the development

A fierce development race of embedded computer controlled durable goods – automobiles, household apparatus and others – has spurred its way toward further sophistication and higher functionality. A short life cycle is one of the aspects that characterizes many of these products, which induces entries from many other countries especially leveraging their cost merits. The technological capability of developing countries is steadily improving.

The situations surrounding the development of embedded software are drastically changing as described below.

(1) Sophistication, complexity, and bloating

As products incorporate more and more functions with a higher level of sophistication, embedded software is also moving toward sophistication, higher complexity and bloating. For example, the volume of software implemented in state-of-the art mobile phones exceeds several hundreds of thousands of steps even in model-dependent portions. The total volume of development – including OS and middleware software – far surpasses those of the backbone systems in major commercial banks, a representative example of enterprise information systems. The volume of the software implemented in a hybrid car (a vehicle with both a gasoline engine and electric motor) surpasses the level of ten million steps: this volume roughly equals the amount of software possessed by each of the major commercial banks in around 1990. [10]

The emergence of multiprocessors - a computer with multiple core (arithmetic circuitry) mounted in it – and networking among products provide factors leading to further sophistication, higher complexity, and bloating volume. (Figure 3)

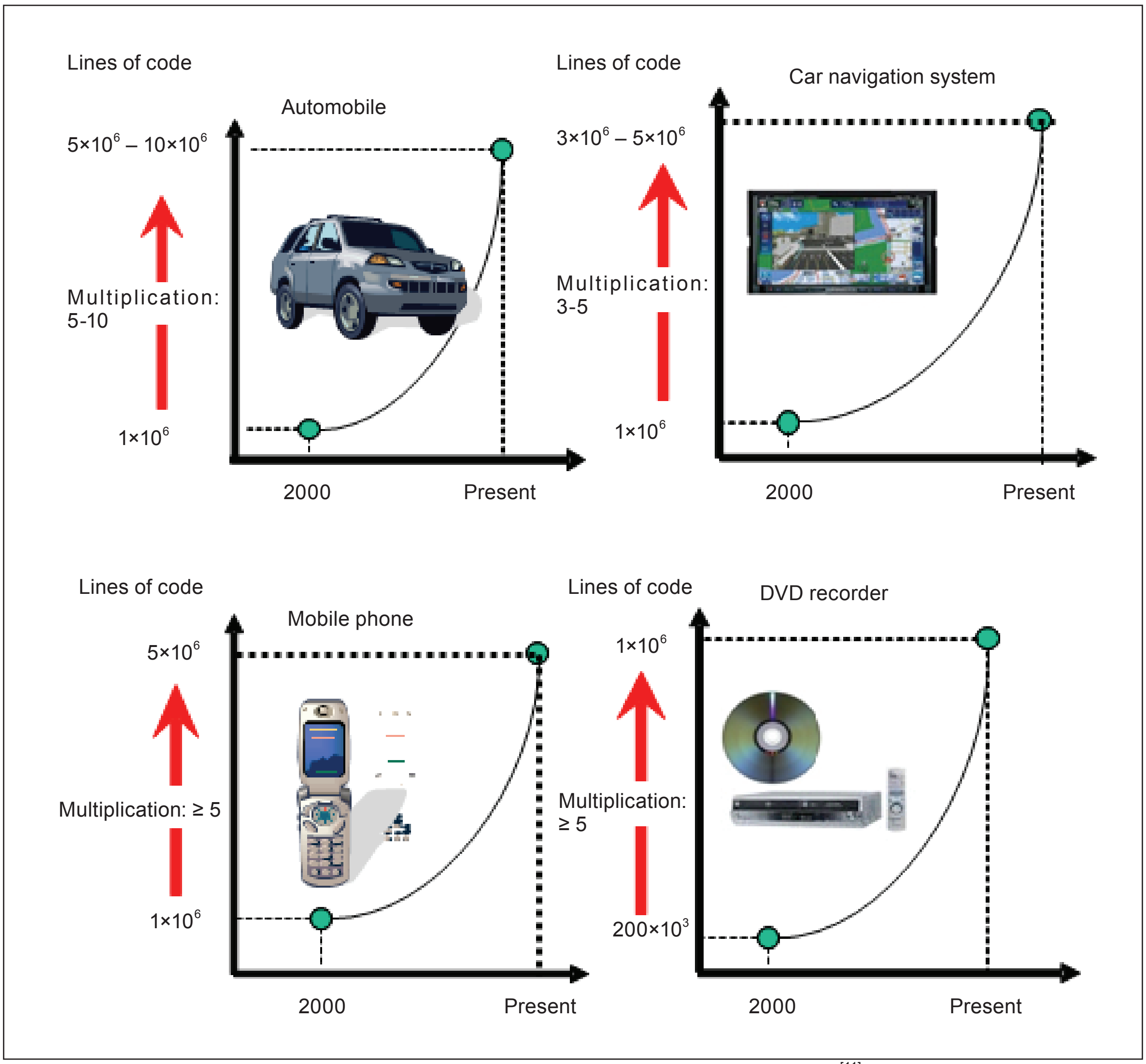

Figure 3 : Rapidly growing size of embedded software[11]

(2) Shortening of delivery schedule

Shortening of products' life cycles is particularly prominent in the Japanese market. Quarterly release of brand-new products is a common practice in the individual-oriented market that includes home electronics and information terminals. For this reason, a delivery schedule for embedded software as short as three month is not uncommon.[12]

(3) Requirements for quality upgrade and cost reduction

Nearly 60% of malfunctions found in embedded software-controlled products are caused by software failures (Figure 4). Upgrading of quality is needed to cope with this situation. In addition, efforts to reduce development cost are also required. These two factors are ever-present requirements, but they are gaining a higher profile against the backdrops of the increasing size, sophistication, and complexity of software, and the shortening of delivery schedules.

(4) Offshoring

As with other categories of software, the development of embedded software is basically characterized by its labor-intensive nature. As software development, especially in Japan, has given rise to a common conception that it is tough and demanding, the current situation will not allow a substantial increase of software developers in spite of the increasing demand. The situation leads to wider outsourcing (offshoring) to overseas developers in the areas centered in China and India, driven by the strong requirements for cost reduction (Figure 5).

3-3 Challenges facing the current R&D system in Japan

The manufacturing sector is the main engine in Japan's visible trade balance, wherein embedded software plays a substantial role especially in the areas such as automobile and electric equipment (these two areas command around 60% of the total volume of export).[14]

In general, development of a product involves several steps from planning to prototyping. If it is embedded computer-controlled, both hardware and software have a direct bearing on each step of the development effort (Figure 6). Because of a close link with the physical entity, the development of embedded software is an area where *suriawase* can make a significant contribution. High quality gained through *suriawase* has much to do with the international competitiveness of Japanese products.

Stages for *suriawase* can exist in each of the development steps - planning, design, and prototyping. This means engineering and work processes involving fine coordination of each component to achieve higher performance and quality as an integrated whole.[15] On the other hand, *kumiawase* (combination) means assembling parts by clearly defining interface specifications and

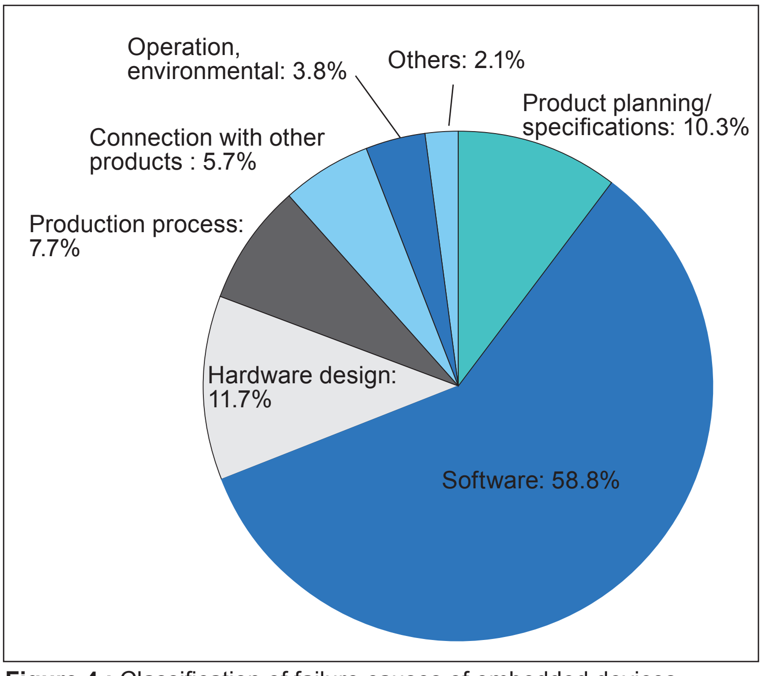

Figure 4 : Classification of failure causes of embedded devices (software and hardware) (FY2008)

Prepared by the STFC based on Reference[7]

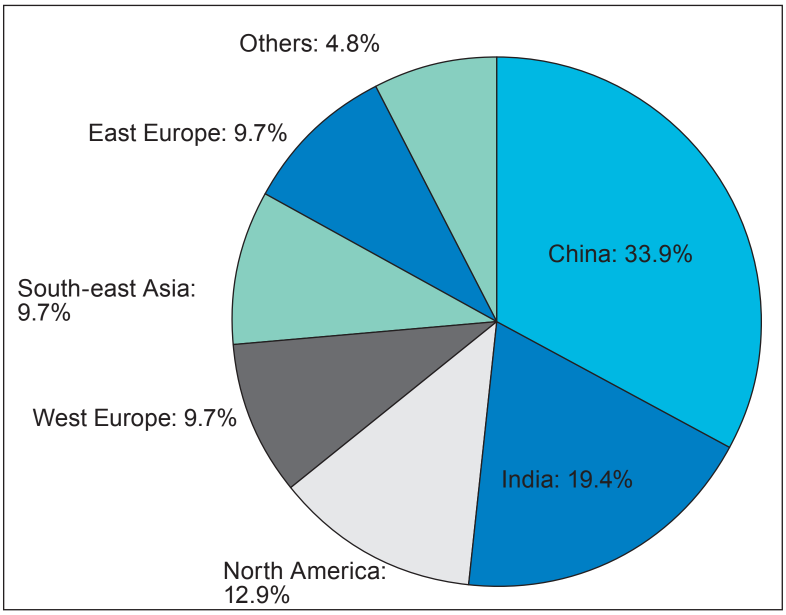

Figure 5 : Offshoring destination of embedded software development from Japan

Prepared by the STFC based on Reference[13]

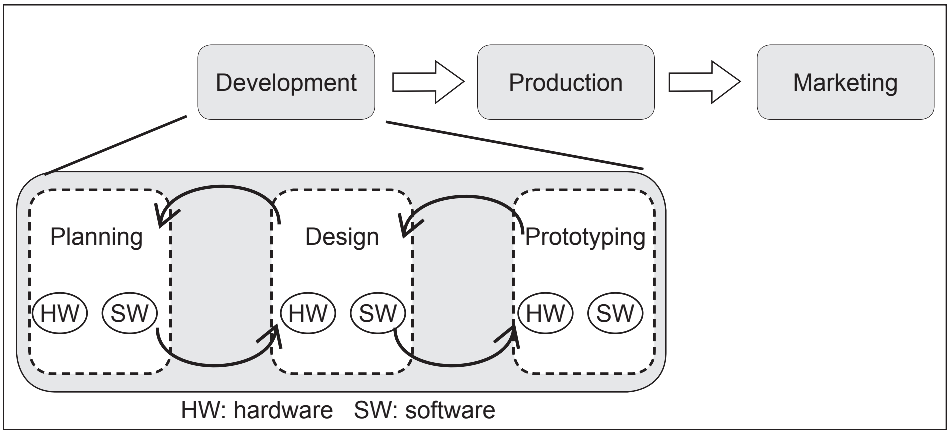

Figure 6 : Development processes of computer controlled embedded devices

purchasing an optimum set of components.

Many of the factors that change situations surrounding development, as described in Section 3-2, have an effect of reducing the effect of the suriawase approach. In Japan, embedded software was traditionally positioned as an ancillary part of hardware, and was developed as such. Although software development became detached from hardware as the size of system development grew increasingly larger, the development environment has still been dominated by the craftsmanship of software engineers who are quite knowledgeable about hardware. But the craftsmanship approach naturally shows its limitations, as the scale and complexity of software become so overwhelming.[16] The suriawase approach represents repetitive coordination for better understanding among the involved parties aiming at an optimized product. But progressively shortening the delivery schedule does not allow enough time for these reconciliation efforts, i.e. *suriawase*.

It will not be easy, in the future like in the past, to move out of touch with Japan's longstanding forte, suriawase, and move to kumiawase. It is not necessarily beneficial for Japan to abandon its traditional source of superiority easily in view of research and development competition with other countries. Therefore, what we need is our efforts to overcome the current situation while maintaining our traditional forte, suriawase. The following challenges must be achieved to that end.

Challenge 1: Establishment of development processes capable of rapidly meeting diverse needs

We should establish the method to take in the diverse needs in development processes and rapidly reflect them in the products, while leveraging the features of suriawase.

Challenge 2: Further upgrading of quality and cost reduction
We should aim at improved quality and reduced development cost taking advantage of the benefits of suriawase.

4 Basic Concept for Strengthening Embedded Software Development

(1) Avoidance of cost competition and pursuit of high added value

Highly sophisticated and complex products generally have a modularized internal structure. If the inter-module interface is clearly defined and made open, purchasing and combining an optimum set of modules – in terms of both performance and pricing – will constitute the main part of the development (i.e. kumiawase). This scheme enables relatively straightforward product development, opening up a wider market for new entries. In the areas where de facto standardization of the modules has well advanced, there is little space left for product differentiation, resulting in fierce price competition. On the other hand, in the area where inter-module interface denies rigorous definition, newcomers who desire to enter the market must develop the product starting from modules. Inability to define a rigorous interface forces the developers to undergo repetitive fine-tuning and coordination processes among the modules in their hands (i.e. suriawase).

Product characteristics can be broadly classified into two categories: those capable of an explicit specification such as price, quality, and functions (hereafter referred to as "type A"), and those that deny an explicit specification such as design, convenience, and quietness (hereafter referred to as "type B"). The type A characteristics allow relatively easy access by the kumiawase approach. Therefore, latecomers often probe the market by providing type A products first, and shift gradually to type B products as its market share grows. Many latecomers try to enter into the market taking full advantage of low prices, and existing manufacturers often find it difficult to compete with them in a price rivalry strategy. The existing manufacturers, therefore, try to evade head-on price competition and place priority in exploring high value-added products – i.e. type B products. One aspect pertinent to type B products is the need to clarify the characteristics of the product that can attract the targeted users. The elements that attract users naturally differ for each user; assessment of user needs should be given a priority to realize "attractive quality."

(2) Value of suriawase approach in mature products development

When an existent manufacturer mulls over type B products, it must take into view the maturity of the product in which embedded software is implemented. Return from kumiawase to suriawase is often observed as the product reaches its stage of maturity. [17]

Let us take the automobile for example. In the early stage of its emergence, there was only unclear correspondence between the parts and functions to be realized. As its use became pervasive, correspondence between a part and function became distinctive and clear: a car body provides loading capacity, the engine provides driving power, and the suspension provides vibration absorption. Further diversification of automobile usage was accompanied by growing needs that could only be met through systematic considerations. An integrated approach – as well as elemental aspects such as fuel efficiency, quietness, and safety – is essential to cope with these needs (Figure 7). The reason leading to this situation is based on the widespread acceptance of automobiles in society and their growing maturity as industrial products. At this stage of maturity, a suriawase approach – fine-tuning between the parts to achieve a higher degree of completion as an integrated entity - becomes more suitable than a kumiawase approach – purchasing parts from the open market for assembly.

On the other hand, in the emerging stage of personal computers, it was a common practice for the technologically knowledgeable users to purchase parts (AP, OS, CPU, etc.) and perform assembly themselves. As it entered into a proliferation stage, delivery of pre-assembled computers by manufacturers became the mainstream. We are still in the transitional stage toward maturity, and performance of personal computers is represented in terms of the specifications of the parts included in the assembly - typically the CPU performance (manufacturer, type name, and clock rate in GHz). Of intrinsic importance for the majority of users, however, is the total performance – robust security, stable long-hours operation without causing excess fatigue and without occurrences of

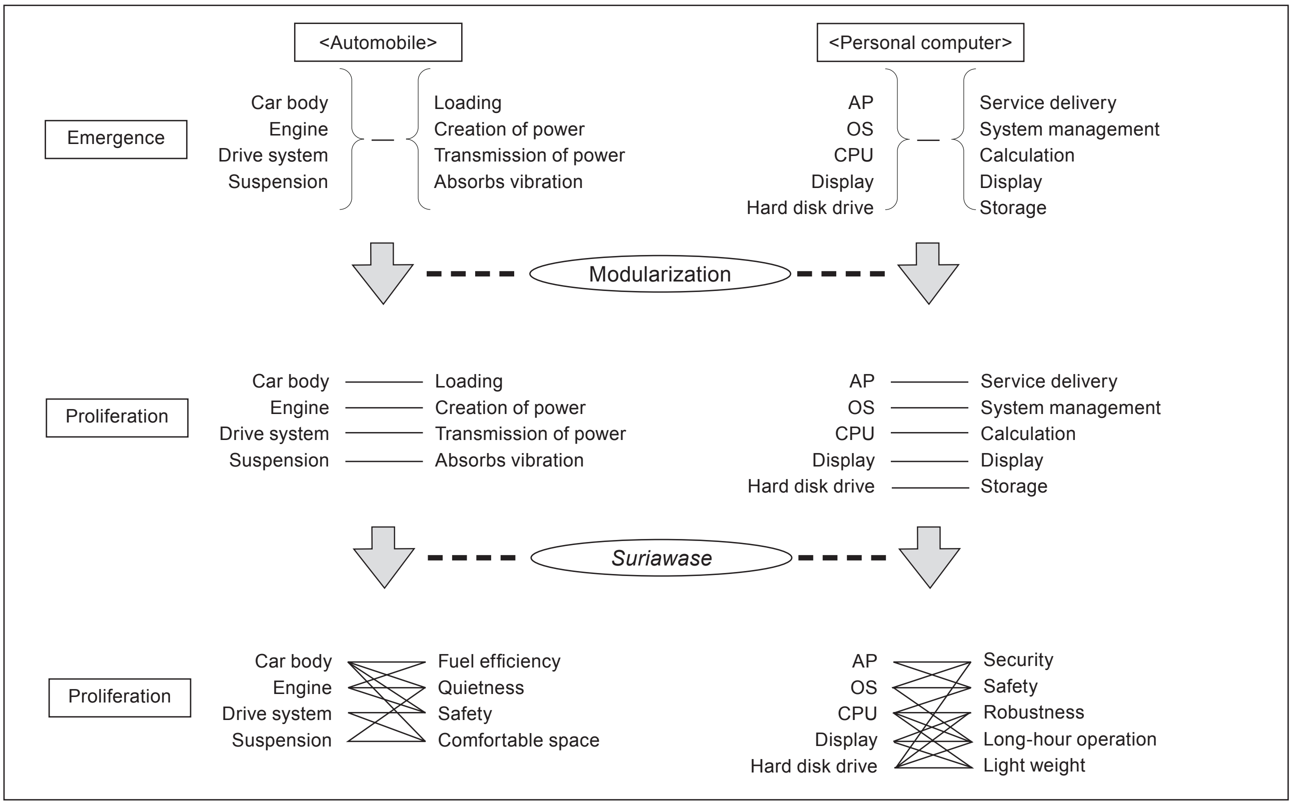

Figure 7 : Transitions of market deployment and inter-component interfacing

Prepared by the STFC based on Reference[17]

hang-up - rather than the superb specifications of the parts included. The need for total performance provides a wider space for suriawase to play an important role (Figure 7).

What is required for the products in their stages of maturity is the development capability to cope with the needs of the majority of users, typically represented in the term "user friendliness." This requires seamless integration of the capacity of each part, which often lies beyond the written details of specifications. To achieve this objective, the conventional process – purchasing optimum parts from the open market and assembling them – will come up short of expectations. Total optimization of the product is needed, where the suriawase approach plays an essential role. Note that, in the later stages of product maturity, the suriawase approach may become unnecessary because of further sophistication of part-to-part interfaces, in which case, advanced modularization using the highly sophisticated parts is expected to proceed again. In other words, the modularization approach and suriawase approach come and go in a spiral fashion as the product evolves.

(3) Two natures inherent to embedded software: package software vs. custom software

Embedded software has a similarity with package software in the sense that each single product is sold in high volume. The former, however, is a material (or an intermediary good) for producing a final product, and as such, does not attract visible awareness from the end users. It also shares certain characteristics with custom software, whose development proceeds all the way accompanied by close references to the hardware to achieve an optimum system.[18]

5 Embedded Software Development features from the Viewpoint of Japan's Social Characteristics

Amid the drastically changing environment for embedded software development, we must have our own edge in the R&D efforts to maintain Japan's competitiveness. Since developing countries are quickly catching up with Japan, it is highly desirable that our forte is invulnerable to imitation. The need for technological innovation is beyond controversy. But, because the fruits of science and technology are based on universal knowledge, they easily propagate and diffuse around the world. In contrast, the knowledge that based on social characteristics does not easily propagate or diffuse in foreign society. Therefore, it is not vulnerable to imitation. That is, recognition of the features of Japanese society and the effort to leverage those features effectively are of utmost importance, in addition to innovations in science and technology, for maintaining and upgrading our long-term competitiveness in embedded software development.

From the viewpoint of characteristics of our society, the following can be pointed out as the strength of embedded software development.

(1) High context nature of communication

In human-human communications, the sharing of context – awareness, value judgment, and experience - is considered to play an important role, in addition to the verbal expression of what a person would like to convey. A higher degree of context sharing (i.e. high context) enables better communication, because it allows getting the message through without expressing all of the content verbally. Japan is considered to be a representative high context society.[19]

Especially, those who have shared time and experience become stable mates facilitating the forming of a social environment where anticipation of other's wishes and tacit understanding work quite effectively. In contrast, in societies with low context sharing (low context society) – typically Europe and America – communication basically depends on verbal expressions. Assigning greater value in expressed language naturally leads to attaching heavier weight to logical coherence, expressive power, and persuasive power.

We cannot simply say which is superior over which: it depends on the situation. Still, we can say that the cost relating to establishing communication is lower in a high context society than in its counterpart, because the suriawase-development does not require renewed detailed verbal expression every time a small modification is made. We, living in a high context society, have a potential to take advantage of the merits inherent to the suriawase approach. On the other hand, there are concerns over the lack of logical coherence in communications, which may present negative aspects in face of the need to compile clearly-stated documents, such as specifications, where pursuit of logical coherence is essential.

(2) Presence of high quality consciousness

The quality of Japanese products is generally highly evaluated, and the signature "Made in Japan" carries a selling advantage outside of Japan. Factors behind the inexhaustible pursuit of quality, sometimes criticized as immoderate, include the attitude of business operators trying to insure the highest quality and highly quality-conscious on-site workers. The strong desire for higher quality on the supply side, however, may be futile if the demand side lacks such needs. The capacity of the supply side and the needs from the demand side must go hand in hand in a quest to achieve high quality products. In fact, Japanese consumers are the most demanding in terms of quality in the world. They are not satisfied with the provision of basic functionality: their request level is so high that they sometimes make complaints about a tiny dint or dirt on the surface of a package.[NOTE 1] Japan has both a highly capable supply side and highly quality-conscious consumers.

(3) Diversified consumptive orientation

As materialistic sufficiency goes widespread, the consumptive orientation of ordinary citizens diversifies. For example, when a citizen ponders buying durable goods, he/she places focus on the product design and fitness to his/her life environment, in addition to its functionality and performance. In the market that embraces a range of diversified needs as in Japan, detailed examination of, and well-suited response to, customer needs is required: provision of products and services designed from a unilateral view of the producers will not be accepted as "pressing."

(4) Experience in custom software construction

Japan has been traditionally evaluated that its international competitiveness in software development is weak as compared to hardware, especially in the field of package software. On the other hand, Japan is said traditionally to have more custom software applications than other countries such as the USA. The custom software is basically developed on a

[NOTE 1]
Some of the overseas electronics companies have established design research laboratories in Japan because: "Annealing our design responding to the most demanding customers in the world will make our product more competitive in the global market." (Nikkei Business, 2009.10.12)

product-by-product basis, and as such, its development requires close and sufficient coordination among system elements including the hardware. Ample accumulation of experience in custom software development, therefore, is viewed to work to the advantage of suriawase-oriented embedded software development.[18]

6 Measures to Strengthen Embedded Software Development That Takes Full Advantage of Japan's Social Characteristics

(1) Construction of rapid prototyping infrastructure involving customers

Let us think of an automobile. The manufacturer knows the basic performance requirements inside out, including such aspect as secure control of the engine and brake system, and these are reflected in its products. On the other hand, to meet the demanding needs of general drivers in value-added aspects - a sense of security in driving and pursuit of comfortableness in variety of situations – the automobile must be put into actual usage to gain hands-on information. But, efforts to improve a product, typically a durable good, after if is put into the market, through feedback from the users, will require a vast amount of cost and time. Therefore, construction of infrastructure for rapid prototyping is required; it should enable taking in user evaluations at an early stage of development, and feeding the modifications pointed out by users directly back into the product development. The prototyping infrastructure should be so constructed that it links Japan's underlying strength in software development – cultivated through custom software development – with the highly quality-conscious consumers, and should also be conducive to picking up the needs that's not documented specifications.

Several attempts have already been made to construct prototyping infrastructures, but they were of seeds-driven nature rather than needs-driven. What we need here is an infrastructure that enables close and timely communication with consumers, leading to the implementation of needs-driven approaches. The construction of such prototyping infrastructure is expected to serve as a mechanism to reject false presumptions on the provider side in the early state of development: assumed functions may be totally unacceptable from the viewpoint of the users and seemingly trivial features may be quite attractive to the users. To facilitate this scheme, diversified

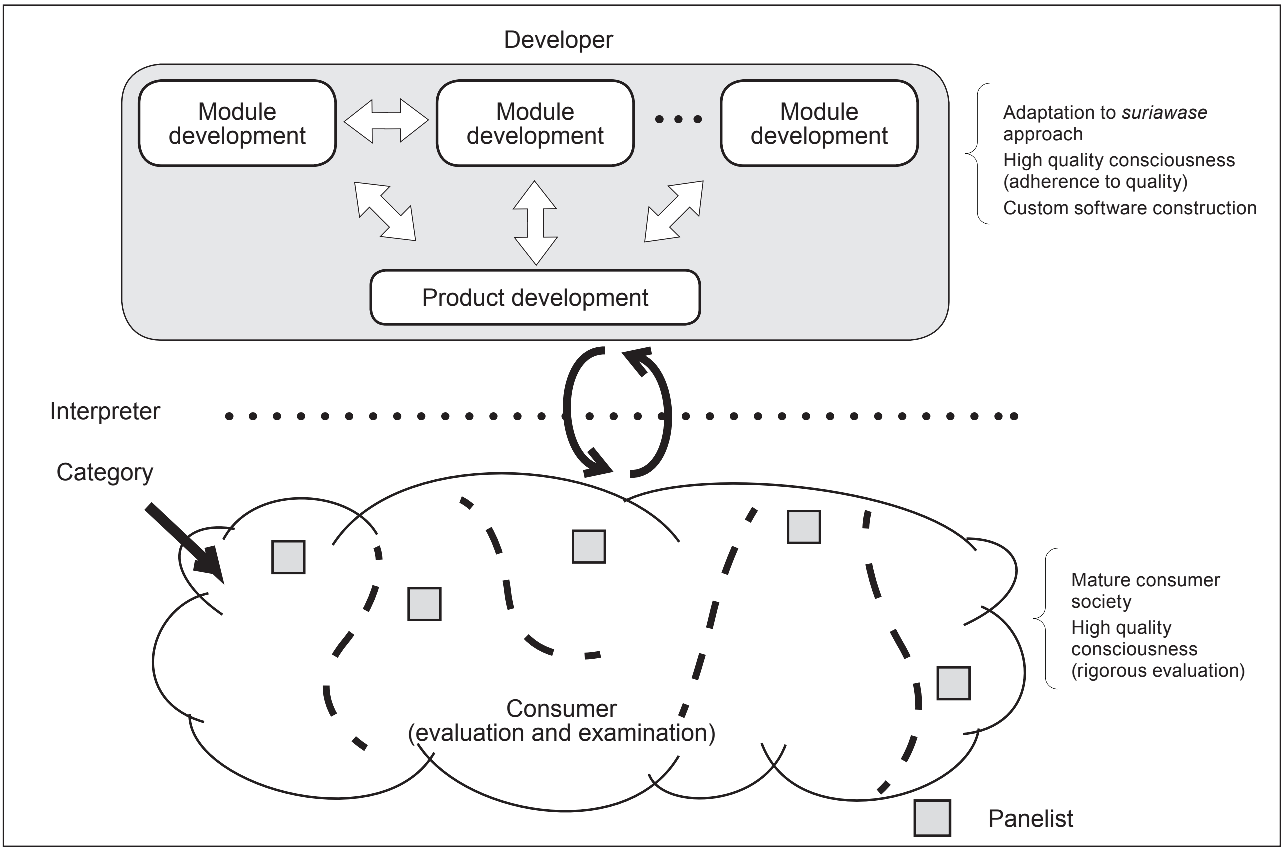

Figure 8 : Needs-driven rapid prototyping infrastructure

consumers may need classification into several categories. For example, a panel consisting of users each representing a category may be an effective tool to entrust the examination tasks of the prototypes. Analysis of information prevailing in cyberspace – Internet websites, blogs, SNS – will also be effective. To exploit this wealth of information most effectively, cultivation and assignment of special personnel will become necessary: relevant persons should be trained to select/extract information for analysis, and serve as interpreters linking developers and consumers (Figure 8).

(2) Build up of logical thinking and communication capacity

The high context nature of our society supports the power of the suriawase approach, but it also raises concerns over the lack of logical coherence in communication. Communication in this context is not limited to simple exchanges of views, nor does it mean affective communication. This means the capacity to persuade others based on clear logical thinking; this requires faithful understanding of the ideas of others, and the ability to build disciplined purposes of one's own. The fact that Japan is suited to the suriawase approach in development by no means eliminates the need to set up inter-module interfaces and purchase optimum parts from outside. Logical thinking is required, for example, to compile the specifications as a clearly written document. Negotiating skill is also required to have discussions with the persons in charge of other processes on an equal basis.[21] The need for such communication skills was also pointed out by a survey that was conducted for business managers and persons in charge in the embedded software sector (Figure 9). There is a sense of apprehension that the software engineers in Japan are currently lacking these communication skills.[NOTE 2]

Language education, especially enriched linguistic education centered in the national language, is of importance to cultivate such skills. Language education in Japan has traditionally shown a propensity to place importance on the emotional aspects of language. There is a view in favor of this propensity that it will serve as a source for strengthening the competitiveness of content software (i.e. animation and games). But, this is not necessarily a suitable approach to cultivate logical thinking. Language education conducive to assimilating logical reasoning should be an integral part of education starting from elementary and secondary stages.[22] In considering the ways of future education, it has been pointed out that closer links among dissimilar subjects – national language, mathematics, science, and social studies – are of vital importance in view of cultivating the capacity of thinking, judgment, and expression. [23] Especially, information education in high schools should enhance proactive coordination with logic education.[NOTE 3]

At present, Japan has around 300 thousand embedded software engineers, and this work force is gaining 10 to 30 thousand recruits every year. [12] Education will take a long time before it begins to exert effect, and may seem to be a roundabout approach, but it has a widespread effect over the whole of software industries in the long run - not limited to human resources cultivation in the embedded software sector. It is expected to have a spillover effect in human resources cultivation in many fields, and thus constitutes an essential part of our future efforts to maintain sufficient international competitiveness in the future.

[NOTE 2]
A software manager made a mockery of the current situation as "ordering parties incapable of writing strict specifications and developers who undestand nothing else but specifications." Business operators in the embedded software sector almost unanimously pointed out that the element in need of strengthening in school education for engineers is communication (dialog) skills, rather than technical ability and business skills. (Ministry of Economy, Trade and Industry, Commerce and Information Policy Bureau: "Actual condition on Embedded Software Industry Survey 2008 – A survey for business managers and persons in charge of operation," 2008) http://www.meti.go.jp/policy/mono_info_service/joho/downloadfiles/2008software_resarch/keiei_houkokusho.pdf)

[NOTE 3]
The new Education Ministry guidelines stipulate such subjects as "Society and Information" and "Information Science" in ordinary high schools, but stress has not necessarily been placed on logical education.

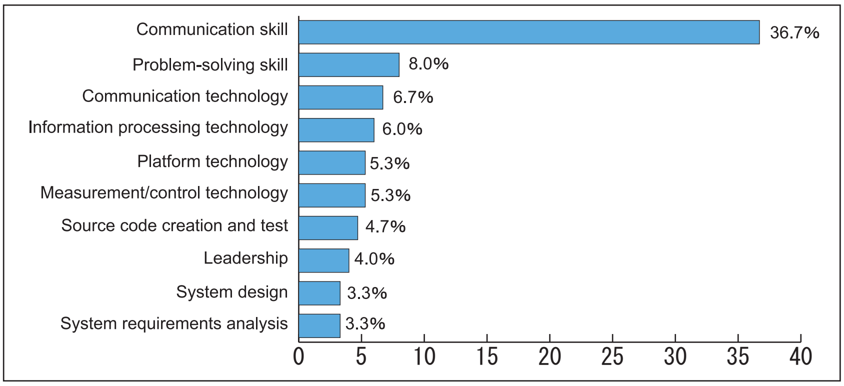

Figure 9: System requirements analysis

Prepared by the STFC based on Reference[13]

7 Concluding Remarks

In this report, the author discusses measures to strengthen the development capability of embedded software in Japan amid the drastically changing situation of rapidly growing capabilities in other countries, especially in the area of durable goods. The author focuses on the underlying characteristics of our society – high context nature, high quality-consciousness, mature consumption propensity, and sophisticated ability to construct custom software - and proposed the following measures based on them: construction of rapid prototyping infrastructure involving the end users, and building up of logical thinking and logical communication capacity.

Automobiles and home electric appliances will be connected to their own network systems, and in turn, these networks will be interconnected with the transportation system and energy system. Integrating them all, a huge cross-cutting social system is expected to emerge in the future that includes all of these networks and electronics driven durable goods in all areas. Embedded software is expected to play a role of enhanced importance in such a huge and complex system. Building up of systematic approaches toward interdisciplinary and cross-organizational review – starting from safety, reliability, and security – is now underway.[NOTE 4] In such social system, convenience and compatibility with life as perceived by the users will become so diverse that the providers will find it very hard to grasp the needs by themselves. Under such situation, rapid prototyping that involves end users, as described in this report, will come into play, and the need for logical thinking and logical communication will increase.

Acknowledgement

In writing this report, the author was helped and inspired through useful discussions with the following researchers. The author expresses deep appreciation to: Mr. Sato SAGA and Mr. Kohji NAGANO (Muroran Institute of Technology), Mr. Masayuki HIRAYAMA and Mr. Yukihiro MIHARA (Information-Technology Promotion Agency), Mr. Hiroshi GOMI (Japan Electronics and Information Technology Industries Association), Mr. Masanori HAGA (COSMOLOGIC), Mr. Junji KIKUSHIMA (Ministry of Economy, Trade and Industry). (Positions listed here are in effect at the time of this research)

[NOTE 4]
For example, the ARTEMIS project in Europe (“Boosting embedded software technology in Japan to world’s top status”: Nikkei Electronics, 2011.6.13, “Report on the trend of automobile electronics,” Japan Automobile Research Institute, 2011)

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(Original Japanese version: published in September, October 2011)