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Parallel Engineering: Our Next Step

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Abstract. Rapidly increasing diversification calls for a new industry fraework. Traditional framwork was linear and sequential. Concurrent Engineering worked very well in these environments to reduce time to market. But to meet widely diversifying requirements, we have to develop another framework to adapt to this situation. Parallel Engineering is proposed. It will enable us to adapt quickly to the changes and we can explore new markets. This framework pivots on emerging technologies in material and in networking. Parts companies will play a central role and by combining these parts, any products can be realized to meet personal preferences and needs of customers.

Keywords. Concurrent Engineering, Diversification, Personalization, New industry framework, Parallel Engineering.

Introduction

Concurrent Engineering (CE) [1] is focused on effectiveness, speed and faster to market. The word "concurrent" came from concurrent computing or concurrent processing [2]. It implies to carry out processes at the same time, which are originally supposed to be processed sequentially. CE was very effective yesterday, when situations did not change appreciably. But today changes are frequent and extensive, so flexibility and fast adaptability are more needed.

This paper points out that industries should move ouf of CE and they should introduce another idea of parallel computing [3] into their framework. Concurrent computing executes computations concurrently instead of sequentially, while parallel computing carries out many calculations simultaneouly.

At the time of CE, industry framework is final-product-based. But such a framework needs a large factory, equipment and many expert workers so that the amount of investment is quite large. Therefore, it is difficult to change their final products, once the production starts.

But if we introduce the idea of parallel computing and develop a new Parallel Engineering (PE) framework, we can secure flexibility and fast adaptiveness. PE will be parts-company-centric and almost any final product can be realized by combining parts. So parts companies can take the initiative in securing a wide variety of final-product customers. Thus, such a new framework is not only flexible and adaptive to the frequent and extensive changes, but the markets of these parts companies will become far larger than those of the current final-product companies. Besides, they do not need such large factories as those of final-product companies and in addition, they do not need so many expert workers. Thus, cost can be reduced to a great extent,

To make such a framework really effective, we have to share knowledge and experience across applications and across industries and make efforts to develop

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versatile parts. To achieve this goal, we have to modularize our product design and share common parts or modules across different applications and across different industries.

It also must be stressed that such modular design will allow customer engagement in design and production and will satisfy their needs of self-actualization [4] and their intrinsic motivations [5]. Therefore, it is strongly expected that our customers will be more attached to our products and will be lifelong customers.

Thus, Parallel Engineering is not only a lifetime value engineering, but a versatile engineering. Concurrent Engineering is, on the other hand, a one-time value engineering on a single track.

1. Concurrent Engineering

The name "Concurrent Engineering" became very popular, since DARPA initiated DARPA's Initiative in Concurrent Engineering (DICE) Project in 1989 [1]. Its motivation was to make US competitive in war. If US finds out that Enemy is developing a better weapon, US has to develop a weapon with the same or preferably better capabilities by the time Enemy realizes it.

So the goal is very clear. Reduction of time to completion with the currently available resources (Figure 1).

A in red indicates US weapon development that is going on. Dotted line indicates Enemy's development. Enemy started to develop their weapon later. But their development is targeted to realize higher functions in shorter time. US found out later that Enemy is developing a weapon with higher performance and it is expected to be realized earlier than US. To be competitive, US must develop a weapon with at least the same performance by the time Enemy realizes it. So US has to take the blue line instead of staying on the red.

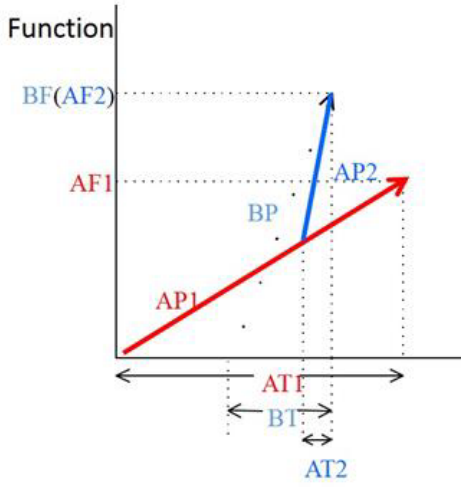

Figure 1. Early CE.

Industrial framework was linear and sequential at that time (Figure 2) and organizations were tree-structured (Figure 3) to maximize productivity, because a tree structure has only one output node so that it works best for this purpose.

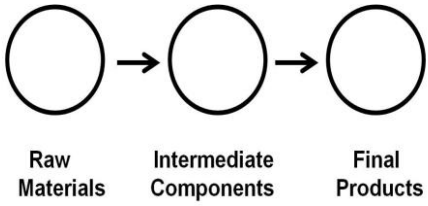

Figure 2. Linear and sequential processing.

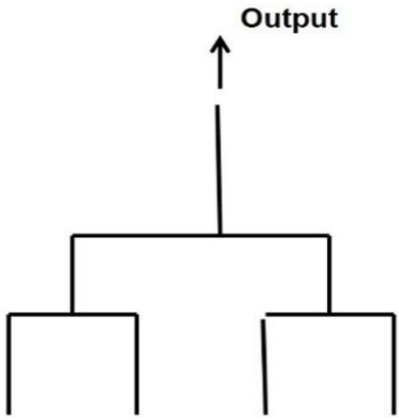

Figure 3. Tree structure.

To achieve their initial goal, such a structure worked effectively for US. But the situation changed. US had to catch up with Enemy. This drove them to introduce Concurrent Engineering (CE). CE brings downstream information upstream and processes them at the same time (concurrenly). Thus, they can reduce time. This idea was originally developed in computing to reduce running time. US applied this idea to weapon production. That is CE (Figure 4).

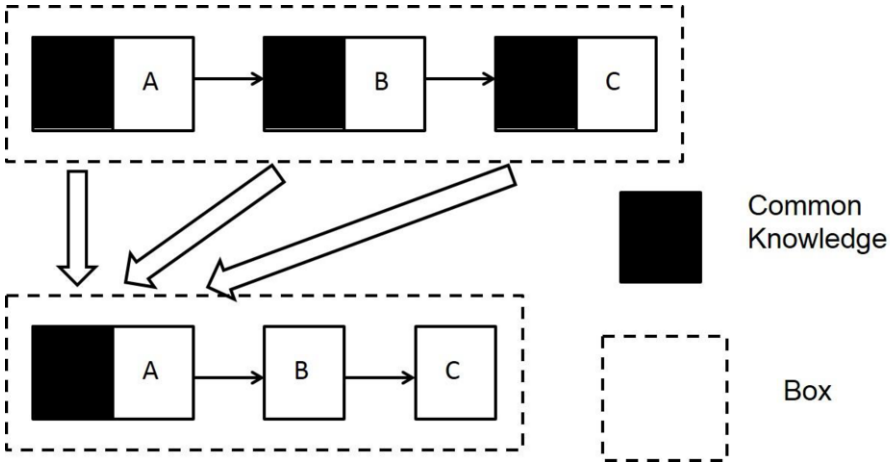

Figure 4. Concept of CE.

As private companies produced their products also in an open loop system and their organizations were tree-structured in those days, their goals were also to reduce time to market to increase market competitiveness. Therefore, CE spreaded very rapidly and extensively among private industries. And indeed it did reduce time to market remarkably.

2. Creeping diversification and personalization

Maslow [4] pointed out human needs start from material satisfaction and move up to mental satisfaction. And finally people want to actualize themselves (Figure 5).

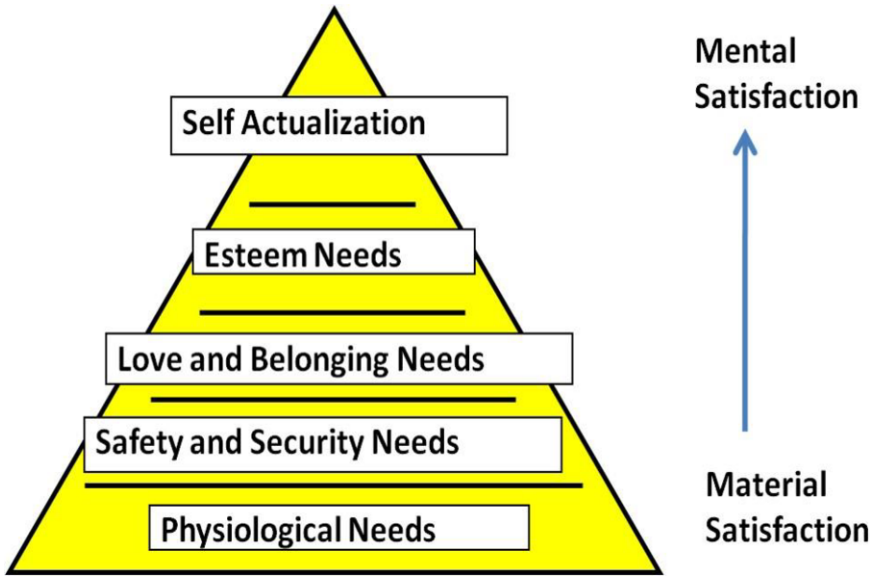

Figure 5. Maslow's hierarch of human needs.

As time went on, people wanted more and more to actualize themselves and the quickly progressing globalization which technological progress brought changed the world and people's requirements were quickly diversified and personalized.

When people wanted products, shorter time to market brought market competitiveness. But such a strategy was quickly losing effectiveness. So their next strategy was to provide a very wide variety of products. They thought customers would pick up what they want. But this strategy did not work so well, becausse people are wanting mental satisfction more than material satifaction. They would like to have their dreams come true. Biologists say that only humans can think about the future. It is the privilege of humans to dream [6].

Engineering is an activity to make our dreams come true. That is why humans are called Homo Faber (Man makes a tool). We take the trouble to make a tool to realize our dreams. Animals can use tools. But they pick up things from nature and use them as tools just for the immediate purposes. The current strategy of producing a wider variety is nothing other than regarding us as animals. Customers would like to make their dreams come true. Yesterday, they wanted material satisfaction. But now they are looking for mental satisfaction.

3. Creative customers

As people wanted products for a long time, we have been regarding them as consumers. But they are not passive consumers. They are very active and would like to customize our products.

Let us take children for example. They are very creative and invent many new ways of sliding down. Inventing new ways provides them with the same amount of, and often more satisfaction than sliding down in the usual manner. This is their challenge and challenge is another self actualization and it also satisfies their desires to learn to grow [5] (Figure 6).

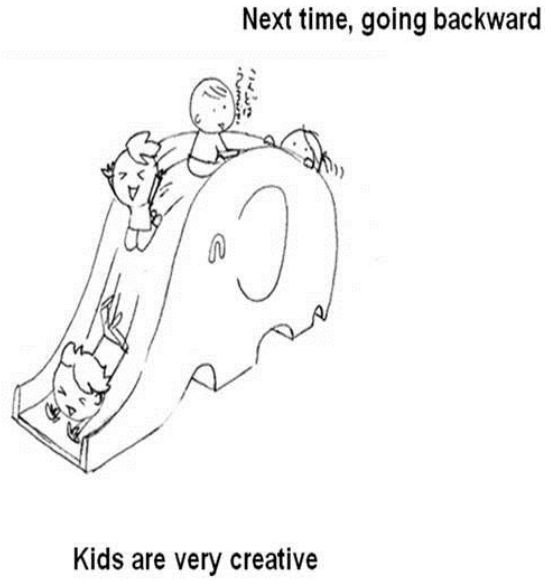

Figure 6. Creative children.

Let us take another example. Young people introduce holes into their new jeans. As a product, those without holes are more valuable. Then, why do they do that? It is becausse they would like to share stories. Jeans are work clothes so if there are holes, they can create stories. This also comes from their human needs (Figure 7).

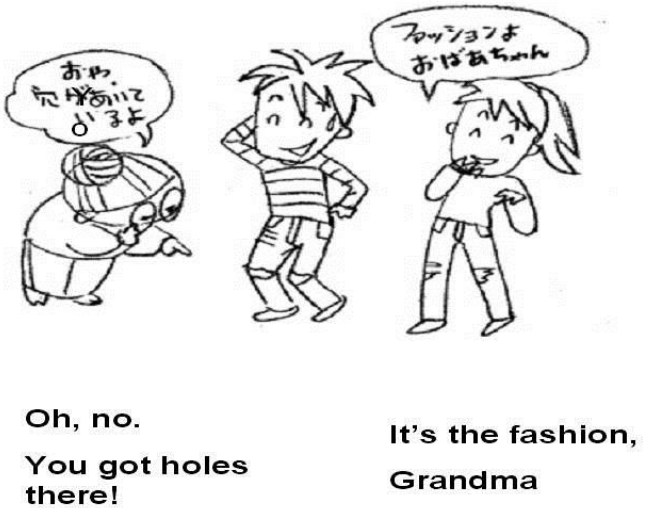

Figure 7. Creative young people.

4. Processes also yield values

Then how can we treat our customers not as animals, but as humans and satisfy them? Lego gives us a hint (Figure 8).

Figure 8. Lego.

Lego sells only blocks. But by combining them, we can realize many different things. They sell process values. They are not selling products. The processes provide people with the joy of self actualization. They enjoy the processes. They enjoy challenges. They enjoy learning to grow.

Lego reminds us of another computing approach, i.e., parallel processing. We have been focusing our attention only to final products and forgot all about the processes. We, engineers, have been thinking that products have value and it is most important how we can develop products with better performance. We forget completely to think about processes. Processes also yield values. Or more often, they create more values than products. We, engineers, have regarded processes just as cost increasing factor. Cost reduction was of paramount importance to engineers until now, so processes were just regarded from the standpoint of cost.Value is defined by the following equation.

$$Value = \frac{Performance}{Cost} \tag{1}$$

We have related processes only to the denominator, because we have interpreted performance as functions of a final product. But performance is not just functions. It includes processes, too. With the same musical instrument, we enjoy different musics. Thus the same product provides different performances. Thus, we should consider processes as numerator. Then, how can build up an industry framework which generates value from processes?.

5. Modularization

Before we consider this issue, let us take a look at the prevailing changes which are taking place in industry now. First, let us consider modularization. Modularization has been practiced since long time ago in engineering. Why it is spotlighted now is because it is considered a versatile and flexible way to respond to diversification and personalization. If we combine them differently, we can come up with many different products, just like Lego.

But most of modularizations used to be functional modularizations. But today emotional modularization is getting attention. Emotional modularization has been practiced for a long time in fashion industry. They modularize dresses, etc so that they can respond to personal preferences of customers. Now other industries are following suit. Daihatsu developed Copen. Its parts are changeable (Figure 9 and Fig.10).

Figure 9. Daihatsu Copen.

Figure 10. Changeable parts.

Currently, these parts are produced by experts and must be changed by experts. But remarkable progress of additive manufacturing, 3D printing [7], etc. will soon make it possible for customers to produce them by themselves. And if we change our design into this direction, customers will be able to change them as they like and whenever they like. So the day of car code is knocking the door.

6. Networked Society

Since Internet of Things (IoT) [8] and Cyber-Physical Systems (CPS) [9] were proposed, networking progressed rapidly not between human and human, but between product and product and between product and human. Recent proposal of Industries 4.0 [10] now connects industries.

Up to now, industries have been making efforts to be the best player. But as Knute Rockne, famous American football coach, pointed out,11 best does not necessarily builds the best team. Best 11 is the way to build up the best team. In fact, Rockne demonstrated this by changing University of Notre Dame to an invincible team.

So we have to say goodbye to producing a single best product, because products are now starting to work as a team. What is important for industries is how they can form a product team that works comfortably, flexibly and adaptively in response to the changing situations and contexts. What customers want now is not everlasting superior functions, but flexibility and fast adaptability to accommodate the frequent and extensive changes of today.

If the structure is a network, any node can be an output (Figure 11).

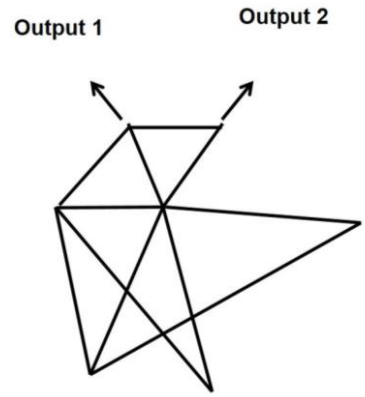

Figure 11. Network

Then, how can we change our industry framework into a network?

7. Parallel Engineering

As described above, CE originated from the idea of computer processing to reduce running time. But we have to remember that when computer scientists talked about concurrent processing, they also discussed parallel processing. How are they different?

Let us consider from engineering viewpoint. Concurrent processing focuses attention to the final result. If processing is sequential, it takes time. So by introducing concurrency, running time can be reduced. But the focus is on the final result.

But if we change our eyes from one single job to the whole jobs, then we can process many jobs at the same time, because they do not have to be sequential. We can process any job, if that processor is idle. Then, what happens if we change our focus from the final product to parts? Different parts do not have to be developed sequentially. In fact, most final product companies are assemblers of these parts or components.

Then, what happens if we build up an industry framework where parts suppliers play the central role? This is just what parallel processing in computing is doing. Such parts- supplier-centric industry framework can lead to such a network as shown in Figure 12.

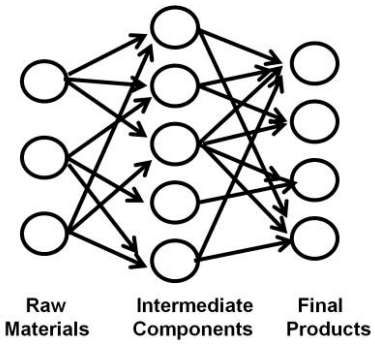

Figure 12. Parallel Engineering industry framework.

It must also be emphasized that the new emerging material engineering enables us to realize such a framework. Although the progress of material engineering has been remarkable, it has been difficult to develop materials, which possess many different attributes customers desire. So engineers had no other choice but to select among what were offered. But such new technologies as additive manufacturing, etc. now enable us to develop materials with any attributes customers desire.

In this framework, parts suppliers do not have be just suppliers to a final product company. They could produce parts which are very versatile and widely applicable. These parts are, so to speak, engineering Lego blocks. So they can be used in wide applications. Thus, parts companies can explore their own markets. In fact, this networked framework will generate a myriad of combinations. They do not have to keep eyes on final product companies any more. Parts companie will play the crucial and central role in developing markets.

This is just the same as what is happening now in soccer. In soccer, forward players were most important yesterday. But today midfielders are increasing their importance. They can see how situations change. They see most of the game. Forward players are focusing their attention to the goal. Why did such a change happen in soccer? It is because the situations change very frequently and extensively in today's soccer. Thus, in the next industry framework, parts companies will lead the whole industry.

The role of final product companies will change dramatically. They will still remain assemblers. But their products changes widely from time to time to respond to the widely changing requirements from customers. They combine many different parts and assemble them to realize what customers want. Their roles will change and tlhey will become important more as service providers and consultants.

And we have to remember that even customers themselves can be combiners/assemblers. Just like Lego, they can buy parts or components and enjoy the work. We should learn from fashion industries. They produce many different clothes, etc. but as dress code indicates, we dress up to suit to the situations and contexts. And we also should mention accessaries. We enjoy how we can combine them. Such different combinations create changes. We have to remember change is another human need. It should also be added that this new network of industry framework is nothing other than a neural network. So it also satisfies our desire to learn to grow.

8. Summary

Recently, industrial environments changed greatly. Yesterday, efficiency was most important. The goal was clear and industries were expected to produce products with better performance in shorter time. But today rapidly progressing diversification and personalization call for flexibility and fast adaptability.

Concurrent Engineering worked very well yesterday. But to adapt to the new environments, industry has to adopt a new framework. Concurrent Engineering worked very well, because it brought downstream jobs upstream and reduced time in sequential production. But changes are taking place frequently and extensively these day and our society is moving rapidly toward more diversification and personalization. So instead of a sequential framework, a network framework must be developed.

Parallel Engineering is proposed here to accommodate such changes and needs. It processes many jobs simultaneously. In this new framework, diversified and

personalized requirements can be answered by combining different parts or components. Thus, the role of parts companies will become increasingly important and traditional final product companies will become combiners and their roles will change to service providers. As a myriad of combinations is possible, there will be many new markets and we can meet customers' preferences and needs more adequately.

References

[1] K. Singh, 1990, *Darpa Initiative in Concurrent Engineering*, Accessed: 07.07.2016. [Online] Available: http://www.dtic.mil/dtic/tr/fulltext/u2/a226394.pdf
[2] Concurrent Computing, 2014, *Wikipedia*, Accessed 07.07.2016. [Online] Available: https://en.wikipedia.org/wiki/Concurrent_computing
[3] Parallel Computing, 2014, *Wikipedia*, Accessed 07.07.2016. [Online] Available: https://en.wikipedia.org/wiki/Parallel_computing
[4] A.H. Maslow, *Motivation and Personality*, Harper & Brothers, New York, 1954.
[5] E. Deci and R. Ryan (Eds), *Handbook of Self-Determination Research*, University of Rochester Press, New York, 2002.
[6] Todaibio, Accessed 07.07.2016. [Online] Available: http://www.todaibio.info, (in Japanese).
[7] H. Lipson and M. Kurman, *Fabricated: The New World of 3D Printing*, Wiley, New Jersey, 2013.
[8] K. Ashton, That 'Internet of Things' Thing, *RFID Journal*, Vol. 22, 2009.
[9] National Scienece Foundation, Accessed 07.07.2016. [Online] Available: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503286
[10] H. Kagermann, W. Wahlster and J. Helbig, *Recommendations for implementing the strategic initiative INDUSTRIE 4.0,* Accessed 07.07.2016. [Online] Available: http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_report__Industrie_4.0_accessible.pdf