Culture: A Key Factor for Implementing the Integrated Concurrent Engineering Approach

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Abstract. Integrated Concurrent Engineering (ICE) is a design approach initially developed in the United States (US) to reduce schedule time and cost while achieving high design quality in the aerospace mission or system design activities. Many organizations in the US and Europe have confirmed these benefits, however, none beyond these regions. In this paper, we focus on a case in which a Japanese organization within the space domain failed to effectively utilize the ICE approach. This case is analyzed from both the systems engineering (SE) and cultural perspectives with comparison to the successes in the US and Europe to identify the main factors differentiating them. The key findings in this paper will provide organizations with information on where to focus in order to successfully implement the ICE approach and any related IT methodologies, and may better inform the strategy for collaboration of organizations within different cultures.

What is ICE?

The information revolution in the 1990's had a huge impact on our lives, and significantly changed the behavior of engineering teams overall and within the aerospace industry. Information technology (IT) leverages the work performance of the individual, and teams derive larger benefit through enhanced communication capability. Many organizations succeed in improving team performance in delivering products with better quality with reduced time and resources, by implementing IT tools and methods in their organizations. However, it is also the case that many organizations fail to improve their performance through information technology. Sometimes they find the best selling tools don't work in their organizations or that new high-tech facilities are just "collecting dust". As the importance and dependency on information technology increases, it is critical to successfully utilize information technology to survive the world-wide competitive situation.

Clearly, skilled and talented engineers are essential to developing high quality products regardless of the process or tools used. Information technology has enhanced individual work performance and team communication performance. This has imposed significant changes on the individual work style but has had little impact on the basic behavior of on-line team communication. The basic style has been the same in the team discussion, brainstorming, and other general meetings during the last several decades while PCs, projectors video conference systems and some high-tech gadgets became popular.

In contrast, well-defined processes and procedures with a supporting environment have changed the basic behavior of the team in the meetings, enhancing team productivity and product quality. ICE is a methodology designed to integrate individual work and communication within the design team, and with other relevant stakeholders. Information technology is the key enabler of ICE approach. Parkin, et al (2003) defined ICE as a real-time collaborative process:

> "Integrated Concurrent Engineering (ICE) is a real-time collaborative process in which a multidisciplinary team discusses a design or analysis problem while concurrently conducting quantitative, computer-based calculations."

They also propose 5 critical elements for successful implementation of ICE:

1. A well-defined set of standard information products for output.
2. Network-linked tools to eliminate manual reformatting of inputs and outputs and to facilitate nearly instant quantitative engineering.
3. Well-understood procedures for real-time collaboration; concurrent quantitative engineering and qualitative conversation.
4. A standing multidisciplinary team skilled in the tools and methods.
5. A facility supporting the hardware, software, and human resources.

These five elements suggest two important points for effective utilization of the ICE approach. The first point relates to how well the design team members communicate with each other in two channels in real-time: (1) quantitative information through design tools and integrated network infrastructure, and (2) qualitative information through face-to-face communication. The second important point is how well the organization improves capability and usability of integrated information infrastructure and skills of design team members to work under ICE process and its infrastructure.

What are the merits of ICE? There are three main areas where an ICE approach offers an advantage against the classical design approach: (1) schedule, (2) quality of output, and (3) team design capability.

In the classical design approach, occasional meetings are the only opportunity for a design team to exchange their design results and information. They redirect their further individual tasks based on the discussion and go back to their respective work places to spend at least several days on assigned tasks. In many cases, team members who have finished their individual tasks within a design cycle have to wait the remaining days for others to finish; if they update their data too early, it raises serious issues on version control. McManus (2002) reported that 40% of time spent in product development could be classified as "pure waste" while just waiting for others to deliver the inputs. Worse than this, information and parameters that engineers used for their own analysis or design may have already been updated, and they find their results are meaningless. Long intervals for information exchange are a serious source of low team productivity.

Intensive and close communication has been one of the main sources of competitiveness for Japanese companies in product development and manufacturing. This sometimes forces the design team to work long hours because they need adequate numbers of meetings and discussions. ICE, on the other hand, can improve the communication capability in a team by utilizing the growing performance and capability of information technology. ICE does not automate the design processes, but once the design parameters and models are developed, the design team can run the design study cycle very quickly. Information technology leverages the team design performance when it is utilized adequately.

ICE helps a team work toward system optimization via an integrated information system and instant communication. An ICE environment makes it easy for team members to have frequent ad-hoc discussion and reduces the chance of spending a long time without knowing the data update status. Information integration helps team members think holistically using system thinking. People normally tend to hide too much margin in their disciplines and raise the risk of designing a locally optimized system, but data transparency forces them to contribute to total system optimization.

The ICE approach leads a team toward continuous improvement in personal skills, system models, design process, and design environment. People have to work smarter to answer questions and to provide data for analysis by other disciplines. They are constantly put under pressure to improve their skills and tools to spend their time more effectively and to respond more rapidly. The high number of design tasks in a short cycle with the ICE approach provides a good chance that the team will improve the design process, parametric system models and other support systems.

The ICE approach, however, is not without constraints and considerations. It is not easy to smoothly implement an ICE approach within an organization. Adequate investment is required to integrate people, process and information infrastructure; nothing comes without paying the necessary costs. Many reports have pointed out that the design team and the organization had to accept using a new method of working which may require the difficult decision to change their behavior, stepping away from their experienced working style. The design process and supporting environment must be prepared well for a smooth implementation. Team members need to be trained to work under the new process and environment. This may also increase the overhead costs and reduce the flexibility, yet these are key to enable the ICE implementation. Without proper investment in supporting tools and environments, the design session will be slowed or disrupted because of cumbersome data transfer among the team members, operations of design and analysis tools, heavy documentations after the sessions, and other negative factors.

Case Study: Challenge of Implementation in a Japanese Organization

A Japanese organization (referred to as organization A, here after) attempted to implement an ICE approach after determining that many other European and American organizations benefited from implementing ICE. Organization A's main objective for using the ICE approach was to reduce the schedule for system concept design activities by leveraging design capability and utilizing information technology, as they often developed new systems concepts and spend at least several months on the concept design activity. Organization A worked on the ICE implementation from the year 2002 to 2005, but did not succeed in effectively implementing an ICE approach in the end. This case examines the organization background and situation, and the ICE implementation process that the organization took, including major steps, and how it worked.

Organization background and situation. The design study in organization A was usually led by a senior system engineer, and a team worked with "classical" approaches. Engineers performed their design or analysis tasks in their disciplines individually, and exchanged their results in the weekly meetings to set next tasks and due date. The final outputs were assessed by managers and executives to judge if the mission was worthwhile to budget and start as a project. The design process and procedures were highly dependent on the experience and preference of the team members, especially the team leader. Each leader had his personal style. There was no organization standard process for the concept design nor standard format for the design output, and the final report contents differed among the studies while some criteria existed for the phase-up-review. Some showed strong leadership by proposing a baseline design by themselves to drive the design, while others would rather support team communication to encourage discipline engineers to collaborate with each other to drive the design by team. Some leaders preferred to put high importance on the system performance, but others put it on reliability and operability. Some extended the design period into details until they feel it enough, but others finished when they came to the due date, leaving some details to the next phase.

These diversities in concept design activities sometimes reduced the quality of design, but some characteristics mitigated the potential issues and let the team run well without the standard processes. These include:

- Intensive communication among teams helped to build the team;
- All the tasks needed for concept designs were covered by experience without explicit standard documents;
- Engineers understood well how each engineer worked due to the long relationship under the lifetime employment system; and
- It allowed some ambiguity in requirements and designs because they were continuously revising them in the later phases as a characteristic of Japanese style concurrent engineering.

One recognized issue was in the data management. All the data used or created for design by the discipline engineers was usually kept by the engineers who created them. The data were shared person-to-person on a by-request basis. Thus, the data disappeared as time went on and it was difficult to refer to some data created 5 years or more years ago.

Under this circumstance, a manager in the Organization A had a chance to talk to an engineer who had successfully run a Concurrent Design Center (CDC) and performed a number of similar system concept designs in the United States. The senior engineer found four good reasons for implementing the ICE concept in Organization A:

1. To improve satellite design quality for the better concept and system architecture;
2. To reduce design period drastically;
3. To create and maintain unified shared database for concept design studies; and
4. To increase the design capabilities of engineers through design experience, storing and sharing the knowledge and data.

In the year 2002, a manager from Organization A and a consultant agreed to sign a contract for consultation to introduce (not implement) ICE and train engineers to help them become familiar with ICE. This manager was actually not responsible for concept design, but rather responsible for infrastructure development to support engineering activities. We refer to this group as the “IT support group” in this case study. This trial was started by the IT support group and the discipline engineers contributed to the effort. Only one engineer was dedicated to work on this activity in the group at the beginning, and the contribution from other groups was essential. Systems engineers in the R&D department joined the activity right after the consultation started. The relationships of these groups are shown in Figure 1.

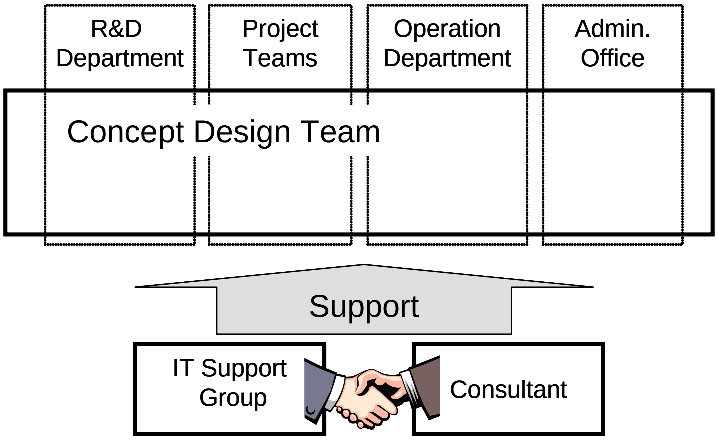

Figure 1. Organization structure of ICE introduction consultation

First step: Consultation for learning an ICE approach. The first step they took was learning what an ICE was and how it worked. This was the reason why it was expressed as introduction not implementation. The consultant was asked to demonstrate the real-time parametric design sessions. This was thought to be the key part delivering the primary value in an ICE concept. As the consultant believed that designing a system in detail at the conceptual design phase would allow them to judge the system feasibility accurately, they were advised to use high-end design and analysis tools. The discipline engineers were skeptical if it would work in the conceptual design, as they felt these tools were burdensome and never used for quick analysis they mainly performed.

The design team was then formed for the demonstration. The consultant led the design session, and the analysis was handled by three discipline engineers and system management. The design infrastructure was developed by the IT support group with the existing equipment. After all the engineers developed the simple models of a sample system in their domain and confirmed the interface, a design session was conducted. The size of some of the components was changed to improve the system performance. Discipline A and B received these changes and ran the simulations to figure out its effects. System management tracked all the parameter sets including the outputs from the disciplines. The data flow among the disciplines is shown in figure 2. Discipline B received the geometrical changes automatically by receiving 3D CAD data in standard format but discipline A reflected the changes manually because of data incompatibility problem. The design cycle time was about 10 to 15 minutes and the session finished in about 90 minutes after roughly optimizing the system configuration and understanding how the real-time parametric design worked.

All the participants understood and recognized two points as the main takeaways from this session: (1) how the real-time parametric design worked, and (2) team design performance improvement with a holistic view was possible.

At the same time, most of the participants pointed out several potential issues in the real-time parametric design. An engineer pointed out that the data flow was too simple to confirm it worked in the system design, because the system to design usually had complicated interfaces and the data flow were not one way. Another engineer mentioned that he did not prefer working under high time pressure as it might cause simple mistakes in the analysis models and his detailed analysis sometimes took a couple of days for optimization. The issues mainly came from the confusion about the drastic process changes and the difference of the situation between the demonstration and the real design activities. Further, they did not have any idea how to modify their tools to fit the real-time rapid analysis.

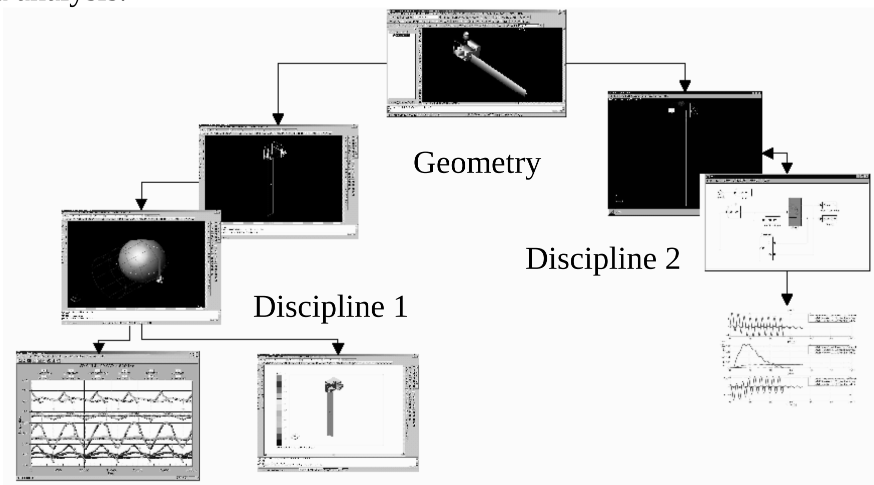

Figure 2. Parameter design flow of the sample system

Their next challenge was how to expand the success of simple and small parts of a system design to a whole system design which was complex, with everything changing dynamically through the design activity. Organization A had performed many concept design studies but the process, tools and data produced in the design studies were not well preserved. They were kept by each engineer and diffused as time went on. The team then selected an imaginary mission and a system engineer and the consultant interviewed the discipline engineers to identify the design process, subsystem models, inputs and outputs, analysis they perform and tools they used in the classical design approach. Several interesting characteristics were identified by analyzing the interview results in Figure 3. These included:

- Much information was exchanged via oral or e-mail communication, and many data interfaces were not clearly defined.
- Most of the discipline engineers handled the input data provided by other engineers manually. They were basically good at handling the stand-alone tools but rarely asked others to provide the formatted data as input.
- Team members closely communicated with each other, but did not optimize their activity at the team level. The data were not inter-exchangeable among the tools and they had to recreate data provided from other disciplines, increasing unproductive overhead workload.
- Most of the engineers executed the analysis with simple tools and spent much time for manual operation. This is because the required analysis varied among the mission and they only analyzed the points where they needed to confirm the feasibility. The output parameters were not solidly defined. High flexibility is the most important characteristics to save the time of the engineers. Thus, they did not invest their resource to develop the automated or well tuned tools and preferred to work just when it is required.

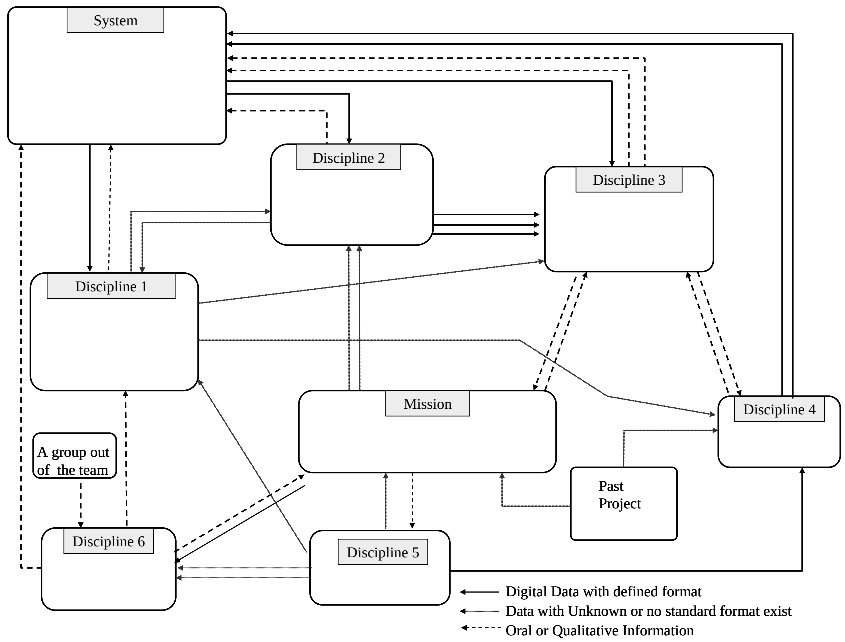

Figure 3. Data interfaces and formats for a system design

After identifying the design process of the classical design approach, while it was not perfect as mentioned above, the team picked up 5 disciplines and demonstrated the mission analysis applying an ICE approach to “feel” how it worked. They held a three-hour design session for three times. Running the real-time design session allowed them to find several more interesting findings if they care to implement an ICE approach. These included:

- **Sharing of the latest design parameters among the team members in real-time.** The design session was not the same as the meeting in an ICE approach. The team members left the discussion to perform the analysis required and went back to the discussion when it was completed. The team leader had to control some discussions and analyses performed in parallel. The design team got confused when working in parallel as they were accustomed to work on a topic as a team. They had to find a way to share the latest parameter set and the analyses conditions for their analyses because the parameters and the conditions changed several times as the design session went on. It appeared to be difficult to do this by intensive communication among the members.
- **Bringing in analysis tools enhanced the discussion in each discipline.** As the team brought their tools into the session, they were able to explain their design and analysis results by showing the details and tool settings on screen. This enhanced the discussion regardless of the confusion on the parameter sharing among the team because the engineers were individually able to provide the detailed parameter settings, assumptions they made, and the details of results without any documentation.
- **Discussion using the data set might negatively impact the flexibility of the team design.** The rapid design cycle produced high volume of design and analysis results for different conditions. In the classical approach, engineers thought over the condition before running analysis tools. On the other hand, an ICE approach lets them analyze more before masking most of the inferior ideas. Thus, the set of results should be well managed to identify what the

high volume data means. The engineers had to communicate with each other using the data sets, and this may conflict with the flexibility in design activity based on the ambiguous data interfaces.

Second step: Success in Mission Sensor Feasibility Analysis. Immediately after the demonstration and the consultation contract were finished, the IT support group was incorporated into the system design group. At the same time, they found an opportunity to apply an ICE approach to a real mission. A pre-project team was required to judge the feasibility of a new concept mission sensor. It seemed like that this study fit an ICE concept because:

- objectives and the system to design were simple and clear enough;
- study area was limited to examining the feasibility of the sensor and the design team would be very small;
- it required a significant volume of quantitative analysis;
- the pre-project members and the lead engineer knew each other's personalities quite well; and
- the pre-project team manager was interested in applying an ICE concept to this study.

They held several meetings to understand the system and develop the system model for design and analysis. Then, they developed the tool set and defined the interfaces to exchange the data online. The flow became quite simple and straightforward as illustrated in Figure 4. As these tools involve both COTS software and the tools coded with programming languages, each team member operated a few tools. All the data created were planned to be exchanged through the network.

Next, two concurrent analysis sessions were performed. Each session took about three hours and analysis cycle time was about 15 minutes. The team discussion stopped all the time when the analysis was required to solve any questions. But, the team successfully managed to restart the discussion in most cases without waiting for getting the results of analyses. This was mainly because the analyses area was limited and that they were able to jump on the different case and come back to the right point where they left off as the analyses were done. The merit of the concurrent analyses was also recognized in data visualization. The cases analyzed were tiled on the large screen to compare the cases. Changing the tile combination or graph size helped them to find some tendency or sensitivity of design parameters.

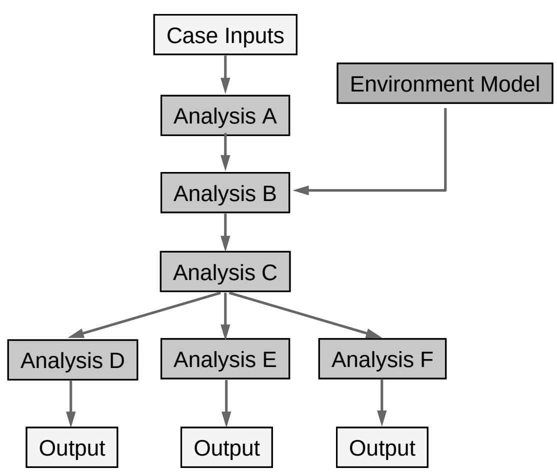

Figure 4. Tools and data flow for the mission sensor feasibility study

There were 22 cases run and 170 graphs were produced by the end of the sessions. While only several cases created the value in these analyses, the pre-project team was satisfied that they succeeded in investigating the solution space very extensively. At the wrap-up meeting, the pre-project manager pointed out the key reasons of this success:

- The mission and input conditions for this study were clearly defined at the beginning.
- Analyses were relatively simple and engineers are well trained for tool handling.
- Tools to compensate for COTS restrictions were developed quickly and worked well.
- Enormous data were created but they were well-visualized for review and discussion.
- In short, well established infrastructure and talented engineers were the keys for success.

While the manager liked the ICE concept used in this study, his opinion on whether this could be expanded to the satellite concept design study was negative. He felt it would be difficult for a large design team to fulfill all the key points above when he considered the current corporate situation and characteristics of satellite system. The biggest concerns were reserving a sufficient number of discipline engineers and reserving their time to coordinate the session and develop tools for the sessions.

The final step: Implementation to Concept Design. The mission analysis case gave some hope to the system design group that an ICE approach would work if it was expanded properly. What they planned to do at this time was expanding the design toolset and let the team transit from the classical approach to an ICE process. There were, however, a few high barriers to overcome.

One barrier was difficulty in real-time design tool implementation. The workforce of the system design group was tightly limited and they were not able to develop all the analysis tools required. The discipline engineers were not eager to develop new tools for an ICE approach because they did not know well enough what tools with what capability were needed. As team members were not the same among the design study, their role was defined flexibly every time. They did not find any merit to developing tools with standard interfaces to connect with others because this did not guarantee that their workload would be reduced. Actually, developing an ICE environment from scratch costed more than the merit of switching the design approach at the first round.

The second barrier was in the organization structure. The discipline engineers were managed by their managers but they were not responsible for the concept design study. Working hard for the ICE implementation was not well-evaluated by their managers. Further, the ICE implementation was only led by the very small part of the organization A. The system design group did not have any support from executive managers, allowing other stakeholders to draw back from this activity.

The third barrier was difficulty in design process renewal. They failed to switch their design process from the classical one to an ICE one because the system design group that led this activity did not have enough human resources for it. They were not able to train engineers, develop an ICE process which fit to the design team and run the required design study with the classical approach in parallel. They were forced to change the design process gradually through the design study, and this introduced inconsistency to some extent. The design study was operated based on the weekly or semiweekly meeting. It had severe conflict with the design study procedures and operation generated by bringing an ICE concept, including the real-time analysis tools, working environment of engineers or quick design cycle, into the meeting.

Finally, after the trial continued for over two years, the organization stopped the phased ICE implementation. While the concept design studies were successful and produced some good outcomes, it was obvious that they were not close enough to succeed in implementing an ICE concept. They found they had to make some other basic changes before trying to implement the tools and process.

Case Analysis

In this section, the case in the organization A described in the previous section is analyzed from both an SE perspective and cultural perspective. The successful cases in Europe and US are referred to as contrasted with the case from organization A, to compare and support this analysis. The goals of this analysis are to understand the roots of the ICE implementation failure, what an organization should or should not do, and how an ICE would be modified to fit Organization A and its traditional Japanese culture.

Flexible task and interface assignment. One of the key cultural factors observed in the case of Organization A was the flexible teamwork and human dependent design process. The team members were assigned their tasks not based on the disciplines, but based on their capabilities. Systems engineers worked very flexibly and collaborated with discipline engineers. They also often worked together by stepping over boundaries of the assignment. This close collaboration enhanced the team communication and maximized the performance and output quality of the team. On the other hand, this flexibility prevented them from defining the standard system models or standard tools because everyone used different models and tools in almost every study. The design tools were not as flexible as the people were.

Stagney (June 2003, Sept 2003) reported a case from an American industry where the first step for an ICE implementation was recording all the design activities and all the data interfaces in a system design. They were surprised when the design team found they had been working inefficiently. This tells us that they had not yet improved the system models and interfaces as a team, but did not have much difficulty in identifying them. In examining Parkin (2003), Mager (2000) and Bandecchi (2000), none of these cases reports success in ICE utilization as mentioned for this issue. The system design group in organization A was not aware of it in their implementation trial. One supporting fact is that most of the engineers hired in the US and Europe works under specific job responsibilities but much more clearly than in most of the Japanese organizations. When the job responsibilities are not clearly defined, they will raise their work performance by doing what they can contribute while each team member has their own main field. This work style will require intensive communication in the team and may cause some efforts to figure out how the engineers are working as a team.

Human dependent design process. The design experience, the process, and the personality of the team members were encoded in the engineers. This was the main reason why the design team in Organization A was able to produce good outputs in the concept design activity without the standard design processes or standard system models. Long term employment culture is one of the enablers. The design and analyses experiences stored in people are transferred to the young engineers through collaboration and communication in the long term relationship. It has worked well in the Japanese culture for a long time.

This human dependent work style is maintained by the hard work of the engineers but this might be the weak point of this style at the same time. The increasing speed of the technology innovation and product life cycle requires them to accelerate by more frequent and intensive communication and collaboration, but this approach will reach its limitation at some time. Further, it is getting to be difficult to memorize all the details of systems and simulate the behavior of the system in one's head because modern systems are getting to be more complex and connected to other systems. The system lifecycle is getting shorter and shorter. They have less time to train the young engineers and transfer the knowledge from seniors to juniors. Thus, while the tacit experience and knowledge transfer among the people is important, it is increasing the necessity of explicitly building up and "visualizing" the systems they designed, the models they developed, parameters they exchanged with others and the toolsets. This leverages the performance of each engineer and the design team Many Japanese organizations have already been introducing this concept and the organization A may need to catch up. It goes without saying that the balance between the sharable standards and implicit experience stored in the engineers is important.

Gradual implementation process. The design team in the organization A was confused by the concept of the ICE approach when they faced it. It was totally different from the classical design approach; repeat discussion and individual tasks. This approach was not welcomed by most of the team members. This reaction was not from the Japanese culture itself but from its organization culture. As Valerdi (2008) pointed out as a critical factors for successful technology adoption, a variety of incentives were required. The team members, however, found little incentives to try the ICE approach. They had to understand the new approach imported from overseas. They had to define the task description to clarify the interfaces for other teammates, and had to develop new design tools to fit the tasks and interfaces. The long term incentives, e.g. reusability of the tools or the system models, visibility of their tasks, high design quality with less time and effort, and so on, did not fully convince them.

The SD team chose the gradual implementation process to avoid the disastrous confusion. They brought design tools and projectors into the meeting room and encouraged team mates to run the simulation and showed the analysis results without bringing the handouts. Some brought the design tools but no one wanted to run the tool as it was not designed for quick turn around. Most of the engineers just brought their analysis results by electrical formats. What they achieved were ecological paperless meetings. They could not go beyond the gap between the classical meetings and concurrent design sessions.

Hesitation for setting tentative design baseline. The design baseline should be identified at the early stage of the design to run the design cycle toward the final design. The stakeholders were able to understand the latest design status and recognize the critical problems they had to solve. The design team members in organization A reacted against this concept. They were not eager to set the design baseline until it is well matured to fulfill the requirements. This might be related to the Japanese culture. "Different" and "wrong" do not have the same meanings in English but they can be translated into the same single word in Japanese, "chigau". Team members thought that changing the design baseline often gives a negative impression to other team members because the design changes imply the original design is not good enough. People prefer to show several design candidates or leave some ambiguity in the design until they finalize the design. This emotional barrier was one of the important cultural barriers to overcome for the ICE approach implementation.

Lack of important stakeholder involvement. There was another reason the organization failed to drive the team members to dedicate themselves to this activity. This was also one of the critical factors for successful technology adoption defined by Valerdi (2008). They did not get good support from important stakeholders including executive managers and discipline engineering group managers. The SD team led this activity but no official support from executives. The ICE implementation trial was just extra work which was not well supported by their management, and was perceived as a constraint to performing the system design. One interesting point was that the engineers often dedicated for the task were not well supported by their management. If the system design team succeeded in motivating the engineers well, they might have had a different result.

Unclear goals and strategies. Organization A could also not define clear goals and strategies to implement ICE. They could not convince the discipline engineers how beneficial the ICE approach would be and that it would be worth the investment. They could not draw the whole picture of how to switch their design approach and step up to the desired situation. These were the main sources of the difficulty for ICE implementation. However, there was no big difference with the successful cases reported by Aguilar (1998), Bandecchi (2000), Mager (2000) and Stagney (2003). The engineers also were surprised when something unexpected happened in implementation and operation. They did not pay much attention to the difficulty of identifying the tasks performed by engineers or the information exchanged by them. A dedicated team was formed under the responsibility of the manager. This meant that there were some big differences between the organization A and others in engineering capability derived from the culture. The ICE approach was well-designed to fit the standard European or American organizational situation. If these differences were not significant, most of the organization might handle this well. When the organization had a much different organizational structure, behaviors and culture, it had to pay attention to these differences and what was required to implement the ICE approach. The clear goals to be shared in the team and well designed implemented strategy would be the answer for it.

Finally, the team did not start with the important tasks, but with the most visible and simple tasks, and then fit themselves into the organizational constraints. The team tried to build the minimum ICE environment without tackling the tough issues and tried to expand and improve incrementally. This bottoms-up and incremental development approach did not work well enough to introduce the needed drastic changes in the behavior of the people. Most of the team member did not understand how the ICE approach can help their activities or improve team design capability.

Conclusion

This paper reports a case of an ICE approach to concept design activity within a Japanese organization, and analyzes it from both systems engineering and cultural viewpoints. Several key factors were identified as the primary reasons of ICE implementation failure. Removing these problems can lead to success in future ICE implementation. However, it does not always work to implement efforts exactly as the successful organizations previously did. Each organization is in the different situation, and they may have different objectives, application areas, corporate strategies, business environments, development experiences, corporate cultures and national cultures to utilize the ICE approach.

Three recommendations to Organization A considering these points are:

1. All team members should understand what kind of differences in culture or organizational situation can be expected by comparing with the successful organizations, first;
2. Focus on defining the design process and system models to be used but leave the toolset, data interfaces and exchange procedures as they are; and

3. Use the simplest tools as much as possible for the quick development and modification to fit the flexible task assignment among the engineers and for the design process identification.

Regardless, the ICE approach conflicts with the traditional Japanese culture, as it was developed based on the American culture. It is natural that copying it will not work well in Organization A, and that it should be implemented with some modification. The most important thing is that ICE helps iterative design analysis investigating the solution space and team communication to organize it. This will work well only if the design team has the basic design capability and understanding of how to decide things based on information at hand. No matter how quickly the communication and analysis is done, it does not leverage the basic design capability of the team.

Therefore, the key question for the ICE approach is “how does the team collaborate to make better decision and produce better designs?” This is the point where the biggest misunderstanding happens in organizations attracted by the ICE approach because the collocation and real-time design does not directly provide for better decision and design. The more important and basic capability for better design is understanding how engineers make decisions based on what information, or what logic and criteria are used for judgment. In other words, the key is how well can the organizations explicitly “visualize” the process and how the models help to sharing throughout the entire organization for better teamwork.

Accordingly, as long as the organization has “visualization” capability and is utilizing it, they can develop their own ICE approach to fit the organization. The collocation and real-time design can be realized in many ways. Culture does matter for how to implement the ICE approach, but cultural factors can be very difficult to identify. If Organization A tries to implement an ICE approach by keeping this in mind, the ICE will work as a powerful tool and leverage design capability in different ways to achieve the success as in cases in the United States and Europe.

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Biography

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