How Do Cultural Differences Affect Utilization of the ICE Approach?

Akira Ogawa
SE Office, JAXA
Marunouchi Kitaguchi Building,
Chiyoda-ku, Tokyo, 100-8260 Japan
+81-3-6266-6609
ogawa.akira@jaxa.jp

Donna H. Rhodes
MIT Engineering Systems Division
Building NE20-388 Cambridge, MA,
02139-4307 USA
+1-617-324-0473
rhodes@mit.edu

Abstract. Integrated Concurrent Engineering (ICE) is a design approach initially developed in the United States (US) for integrating individual work and team communication into the activities of mission design and system design for spacecraft. Many organizations in the US and Europe have confirmed that implementing ICE reduced schedule time and cost while achieving high design quality in these activities. In this paper, a case is presented on a Japanese organization within the space domain that tried but failed to effectively utilize the ICE approach. This case is analyzed from both the systems engineering (SE) and cultural perspectives. Based on the experience and analysis, several key points are derived for realizing successful ICE implementation in the Japanese organization, and these may better inform the strategy for collaboration of organizations within different cultures.

Introduction of ICE approach

The information revolution in 1990's had a huge impact on our lives and significantly changed the behavior of engineering teams overall and in the aerospace industry. Information technology (IT) leveraged the work performance of each individual, and teams derived larger benefit through enhancing their communication capability. Many organizations succeeded in improving the team performance in delivering products with better quality, and with less time and resources, by implementing IT tools and methods in their organizations. However, it is also the case that many organizations failed to improve their performance with information technology. Sometimes they found the best selling tools did not work in their organizations or that new high-tech facilities were "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.

What is ICE? Clearly, skilled and talented engineers are essential to developing high quality products regardless of the process or tools used. However, well defined processes and procedures with a supporting environment can enhance team productivity and product quality. ICE is a methodology 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 proposed 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 to 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 this infrastructure.

What are the merits of ICE? There are three main areas where an ICE approach offers 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 for assigned tasks. In many cases, team members have to wait for the rest of the days after they finished their individual tasks within a design cycle; if they update their data at their own timing, 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 that, information and parameters engineers used for their own analysis or design can be already 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 the source 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.

The ICE helps a team work for system optimization with integrated information system and instant communication. An ICE environment makes it easy for team members to have frequent ad-hoc discussion and reduces the chances 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 margins in their disciplines and raise the risk of designing a locally optimized system, but data transparency forces them contributing on total system optimization.

The ICE approach leads a team to 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 in other disciplines. They are constantly put under pressure to improve their skills and tools to spend their times more effectively and to reply more quickly. High number of design tasks in 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.

However, the ICE 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 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 should be trained to work under the new process and environment. This may also increase the overhead cost and reduce the flexibility, yet these are key to enabling 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.

ICE in Practice

The ICE approach was developed by Aerospace Corporation and implemented at JPL in 1996 (Aguilar 1998). They noted that this innovative design approach improved the spacecraft design quality while cutting the schedule and cost. Many aerospace organizations followed and confirmed it.

One interesting thing is that most of the facilities for the ICE approach have some common features: PCs with analysis tools and visual audio system connected via Ethernet; discussion table at the room center; and interdisciplinary design team with discussion coordinator. While these key facility features are the same, each organization adapted an ICE approach in a different manner for different objectives, and naturally each worked in the different way.

Most of the organizations found the biggest achievement was reducing the design period from months to weeks, but some expectations were not realized. One organization could not reduce the cost while successfully reducing the schedule. One could not establish the standard design process and had to have the dedicated process every time. One found that the design tool set required too much customization for each engineer, and had to be modified when an engineer was replaced. The ICE approach is not a "one fit all" or perfect design approach. Many reports mention that the most important key factor for successful ICE implementation is the design team. How well an ICE works depends on how "good" the team is. This designation looks reasonable but it is questionable if this helps in organization planning when trying to implement ICE. It is obvious that a good team can accomplish things well in general. As such, the important question is what distinguishes a "good" team and "bad" team? In other words, what are the important factors for an organization to avoid an ICE approach implementation failure?

An ICE Implementation Challenge Case in Japan

A Japanese organization (referred to as organization A, here after) attempted to implement an ICE approach after determining that many other Euro-American organizations benefited from implementing ICE. Organization A's main objectives for using the ICE approach were to reduce the schedule for system concept design activities by leveraging their design capability and utilizing information technology, as they often develop conceptually new systems and spend at least several months on the concept design activity. They worked on the ICE implementation from the year 2002 to 2005, but did not succeed in implementing an ICE approach at the end. This case (Ogawa 2008) examines the organization background and situation, the ICE implementation process the organization took, the major steps, and how it worked.

Organization background and situation. The design study in organization A is usually led by a senior system engineer, and a team works with "classical" approaches. Engineers perform their design or analysis tasks in their disciplines individually, and exchange their results in the weekly meetings to set next tasks and due date. The final outputs are assessed by managers and executives to judge if the mission is worthwhile to budget and start as a project. The design process and procedures are highly dependent on the experience and preference of the team members, especially the team leader. Each leader has his style. There is no organization standard process for the concept design or standard format for the design output, and the final report contents differ among the studies while some criteria exists for the phase-up-review. Some show 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 prefer to put high importance on the system performance, but others put it on reliability and operability. Some extend the design period into details until they feel it enough, but others finish when they come 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 are shared person-to-person on a by-request basis. Thus, the data disappear as time goes 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 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 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, and 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. Actually the manager was not responsible for concept design but responsible for infrastructure development to support engineering activities. We refer to this group as "IT support group" in this case study. This trial was started by the IT support group and the discipline engineers contributed to it. Only one engineer was dedicated to work for this activity in the group at the beginning, and the contribution from other groups was essential. Systems engineers in R&D department joined the activity right after the consultation started.

The relationships of these groups are shown in Figure 1 below.

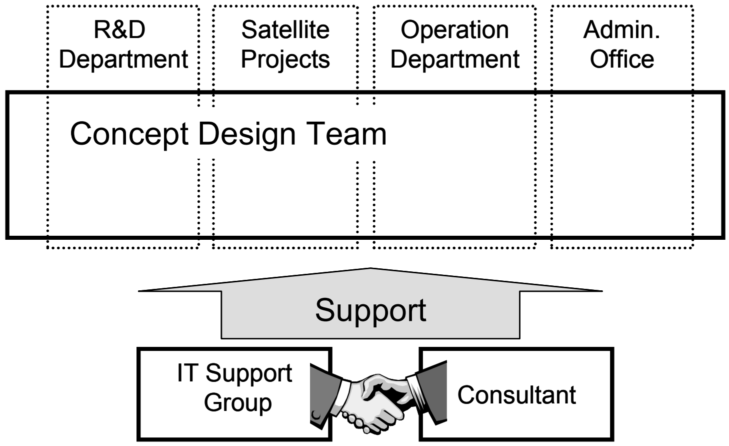

Figure 1. Organization structure of ICE introduction consultation

First step: Consultation for learning an ICE approach. The first step they took was learning what an ICE was and how it worked. This is the reason why it is 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 which delivered the main value of 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 because they felt these tools were burdensome and never used for quick analysis.

The design team was 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 components was changed to improve the system performance. Discipline A and B received the 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 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 is too simple to confirm it works in the system design because the system to design usually has complicated interfaces and the data flow is not one way. Another engineer mentioned that he did not prefer working under high time pressure because it can cause simple mistakes in the analysis models and his detailed analysis sometimes takes 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 quick analysis.

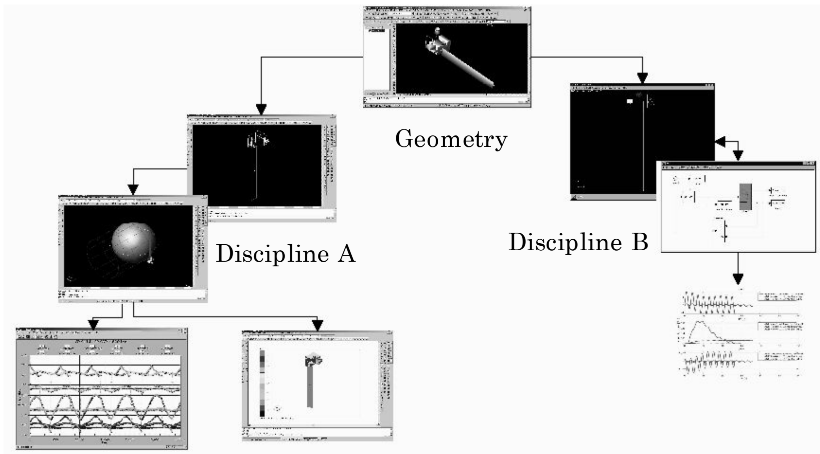

Figure 2. Parameter design flow of the sample system

Their next challenge was how to expand the success of simple and small parts of a system design to a whole system design which is 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 are kept by each engineer and diffused as time goes on. Then, they 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 use in the classical design approach. Several interesting characteristics were identified by analyzing the interview results. These included:

- Much information is exchanged via documents or oral 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.
- Some disciplines created the same data respectively.
- Team members closely communicate with each other, but did not optimize their activity at the team level (but individual level). The closed data formats among the tools were not unified and they had to recreate the data provided from other disciplines. This increased their 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.

After identifying the design process of the classical design approach, while it was not perfect as mentioned above, they picked up 5 disciplines and demonstrated the mission analysis applying an ICE approach to "feel" how it worked. They held three hour design session for three consecutive 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:

- **Balance between discussion and analysis should be controlled well.** The design session is not the same as the meeting in an ICE approach. The team members perform the required analysis and go back to the discussion only if needed. The team leader had to control some discussions and analyses performed in parallel. The design team got confused when working in the session as they are accustomed to the normal meeting. Some training should be provided to run the design session smoothly.
- **Bringing in analysis tools leads to deep and further discussion.** As they bring 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 because the detailed parameter settings, assumptions the engineer made and the details of results were not written down on the document provided in the meetings.
- **Huge amount of data is created in quick design cycles that must be managed well.** Quick 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 let them analyze more often. Thus, the set of results should be managed well to identify what the high volume of the data means by any means.
- **Recording what the team performed in the session is essential**. As many small discussions and many parametric analyses were performed in the design session, it was really difficult to follow what the team performed by the end of the three hour session. This did not happen in the classical approach because only a few design cycles ran in the meeting and the snapshot was taken at the end of the meeting.

Second step: Success in Mission Sensor Feasibility Analysis. Right 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 will fit for an ICE concept because:

- the objectives and the system to design were simple and clear enough;
- the study area was limited to examining the feasibility of the sensor and the design team will be very small;
- it requires a significant volume of quantitative analysis;
- pre-project members and the lead engineer know 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 straight forward as illustrated in Figure 3. As these tools are with 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.

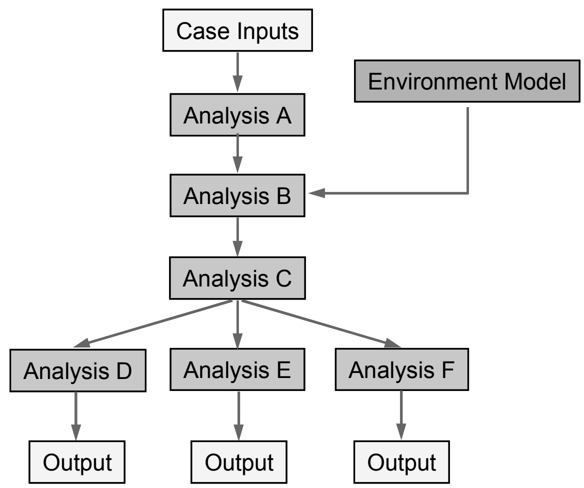

Figure 3. Tools and data flow for the mission sensor feasibility study

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 is 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.

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 of this study.
- 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 keys for success.

While the manager liked the ICE concept used in this study, his opinion on if 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 the sufficient number of the discipline engineers and reserving their time to coordinate the session and develop the tools for the sessions.

This meeting was closed with the team recommendations as follows.

- Multiple screens are desirable even for the simple analyses session as in this study.
- Automated data processing tools for final report are required to handle the substantial amount of outputs.

- Some action should be taken to reduce the noise from the projectors and PCs in the room.
- The leaders need operation capability which enables keeping members' motivation high enough throughout the long session.

The final step: Barriers to Implementing 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 do at this time was expand 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 are not the same among the design study, the role of them are 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 costs more than the merit of switching the design approach at the first round.

The second barrier was in their 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 the executive managers. This allowed the 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. Bringing an ICE concept (including the real-time analysis tools, working environment of engineers or quick design cycle) into the meeting just generated conflict with the design study procedures and operation.

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

Case Study Analysis

In this section, the case in the organization A is analyzed from both an SE perspective and cultural perspective. The goals of this analysis are to understand the roots of their ICE implementation failure, what they should or should not do, and how an ICE would be modified to fit Organization A and its traditional Japanese culture.

Analysis from SE perspectives

Lack of design process identification. The ICE approach was totally new to Organization A. It was an appropriate and important step to understand how it works by hiring a consultant.

However, they mainly focused on finding how the tools were used and information was exchanged in the real-time session, and defining the subsystem models and design parameters with the discipline engineers. They did not try to identify their actual current design process and total system model.

Unclear goals and strategies. They also could not define the clear goals and strategy to implement ICE. They could not convince the discipline engineers how beneficial the ICE approach would be and 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 main sources of the difficulty for the ICE implementation.

Absence of design standards. The continuous changes of the team members added additional challenges to building the entire process and system model. This brought unclear requirement to the real-time design tools and tool interfaces. The subsystem model, design approach, tasks and the depth of analysis varies among the engineers because there was no common understanding of them and this made things complicated.

Unsuccessful team building and management. They could not force the team members to dedicate themselves to this activity because they did not get good support from important stakeholders including executive managers and discipline engineering group managers. The ICE implementation trial was just an extra work which was not well supported by their management, and was perceived as a constraint to performing the system design.

Finally, they did not start with the important tasks, but with the most visible and simple tasks, and then fitting 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.

Analysis from cultural perspective

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 are assigned their tasks not based on the disciplines but based on their capabilities. Systems engineers work very flexibly and collaborate 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.

Human dependent design process. The design experience, the process, and the personality of the team members are encoded in the engineers. This is the main reason why the design team in Organization A was able to produce good outputs in the concept design activity. Long term employment culture allows this. 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. Thus, while the 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.

Conclusion and Recommendation

The paper reports on 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 main reasons of the ICE implementation failure. Removing these problems can lead them to success in future ICE implementation. However, it is not always good to implement efforts exactly as the successful organizations previously did. Each organization is in the different situation. They have different objectives, application areas, corporate strategies, business environments, development experiences, corporate cultures and national cultures.

Two recommendations to Organization A are:

1. 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
2. use the simplest tools as much as possible for the quick development and modification to fit the flexible task assignment among the engineers.

Regardless, the ICE approach conflicts with the traditional Japanese culture as it has been developed based on the American culture. It is logical that copying it will not work well in Organization A, and should be implemented with some modification. The most important thing is that ICE helps communication and it 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 the "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 the ICE approach by keeping this in mind, the ICE will work as a powerful tool and leverage their design capability in different ways in order to achieve the success as in cases of the United States and Europe.

References

Aguilar, J. A. et al., "The Aerospace Corporation's Concept Design Center", *INCOSE Annual Symposium 1998 Proceedings,* 1998

Bandecchi, Massimo, et al. "The ESA/ESTEC Concurrent Engineering Facility", *EuSEC 2000 Proceedings,* September 2000

Coffee, T., "The Future of Integrated Concurrent Engineering in Spacecraft Design", *Lean Aerospace Initiative Working Paper Series, MIT,* 2006

Mager, R. et al.,"The Satellite Design Office at Atrium - A Success Story of an Industrial Design Center Application", *EuSEC 2000 Proceedings,* September 2000

McManus, H. "Lean Product Development", *Presentation to the Lean Aerospace Initiative Executive Board,* 2000*, http://lean.mit.edu*

Ogawa, A., "Concurrent Engineering for Mission Design in Different Cultures", MIT S.M. Thesis, February 2008

Oxnevad, K. I., "The NPDT - The Next Generation Concurrent Design Approach", *EuSEC 2000 Proceedings,* September 2000

Parkin, K. L.G. et al., "ICEMakerTM: An Excel-Based Environment for Collaborative Design", *2003 IEEE Aerospace Conference Proceedings*, 2003

Parsaei, H. R. et al. *Concurrent Engineering - Contemporary Issues and Modern Design Tools.* Chapman & Hall, 1993

Syan, C. S. et al., Concurrent Engineering - Concepts, Implementation and Practice, Chapman & Hall, 1994

Stagney, D. B. "Organizational Implications of "Real-Time Concurrent Engineering": Near Term Challenges and Long Term Solutions", *INCOSE Annual Symposium 2003 Proceedings,* June 2003

Stagney, D.B., "The Integrated Concurrent Enterprise", MIT S.M. Thesis*,* September 2003

Wall, S. D., "Use of Concurrent Engineering in Space Mission Design". *EuSec2000 Proceedings,* September 2000

Biography

Akira Ogawa is a system engineer in Japan Aerospace Exploration Agency and contributing to enhance its systems engineering and project management capability. He received his M.S. in engineering and management from MIT and in mechanical engineering from Kyoto University. Mr. Ogawa is a member of INCOSE and INCOSE Japan chapter.

Donna H. Rhodes is a Senior Lecturer and Principal Research Scientist in the MIT Engineering Systems Division, and Director of the MIT Systems Engineering Advancement Research Initiative. She received her Ph.D. in Systems Science from the T.J. Watson School of Engineering at SUNY Binghamton. Prior to joining MIT, Dr. Rhodes had 20 years of experience in the aerospace, defense systems, systems integration, and commercial product industries. Dr. Rhodes is a Past President and Fellow of INCOSE, and is a recipient of the INCOSE Founders Award.