Chapter 4: ICE – In Practice, An Organizational Quagmire

The previous chapter detailed the theoretical advantages that the MATE-CON process has over other popular forms of Concurrent Engineering. But if it is a superior approach to the design of complex systems, why hasn't it become more widely adopted? Is there an inherent conflict between the paradigm of decomposition (that is the basis for most modern organizational structures), and the philosophies that power Integrated Concurrent Engineering and MATE-CON? In order to answer these questions, the implementation of these processes in a real organization must be studied in depth.

Section 4-A: Recent ICE Implementations

Several major organizations have implemented Integrated Concurrent Engineering (ICE) processes in the last 5 years. Their uses range from designing small satellite payloads to large "system-of-systems" communication architectures. While each of these design facilities have been highly successful in achieving their Technical objectives, they each dealt with difficult People and Process issues (Heim et al, 1999), (Parkin, et al, 2003), (Sanders, 2002), (Wall et al, 1999), (Neff and Presley, 2000). Before presenting the detailed case study, the following general lessons can be learned:

- All teams found that a dedicated, "standing" design team was the most powerful approach. True process improvement requires a team to practice a process many times and then to have the authority and accountability to make positive changes.
- The physical layout of the design "home room" was just as important to the team's success as the information-exchange architecture. Communication happened verbally, non-verbally and electronically.
- Strong, passionate leadership was essential.
- The highest-performing team members were those who were able to be flexible and look at the whole system rather than reverting to being subsystem experts only.
- All the teams started with a self-described "crude" information exchange process. They improvised and innovated as they progressed rather than waiting for a large, complicated new software system that was everything to everyone.

Section 4-B: Deep Dive: Overview of Project RTCE

In the last quarter of 2001, a mid-level manager at a large US aerospace company assembled a product development team to create an innovative product design process. This "Real-Time Concurrent Engineering" (or "RTCE") team would be chartered specifically to apply the concepts of Integrated Concurrent Engineering (ICE) developed at CalTech, JPL, MIT and Stanford. In rapid succession, the new RTCE team built customized design tools, validated their technical performance and began generating high quality proposals.

An outside expert initially facilitated the efforts of the RTCE team. The courageous manager who sponsored the project obtained internal development funds based on anticipated efficiency gains in his new product design department. His staff consisted of approximately 75 engineers who were each assigned in a matrix fashion from their functional group on a rotational basis. Although all of these specialists were co-located in the product design department, each retained accountability to their home department, and reported to their functional managers for performance evaluations. This department was essentially a product-development IPT.

The team began by meeting together to identify the entire set of information that would be exchanged during a design session. This exercise began with each subsystem representative listing a very specific set of variables that were required to design a standard product. Other subsystem representatives then signed up to provide the data for each variable during the session. The result was a massive table with several thousand pieces of information that, in the past had all been exchanged manually. Immediately, the team became energized – they realized that they would never again want or have to design products using their old process.

After the needs-identification was complete, each subsystem designer was then tasked with creating a design tool that could translate the requested inputs into the outputs necessary to create a preliminary design. This process took approximately three months.

Figure 4-B-1: Photo of the Real-Time Concurrent Engineering Team at work in their Home Room

Realizing that the new way of working together would encounter resistance from many different parts of the organization, the sponsoring manager put together a comprehensive implementation plan and budget. He met with some senior leaders in the company and passionately obtained their buy-in for the first stages of development. He then challenged his best employees to help him make the concept into a reality. His personal dedication to the new process sent a clear signal to all involved that the RTCE project had absolute support.

The next phase of the implementation involved a technical validation of the new design method. The team leader announced a series of weekly meetings in which the new system would be used to design a product that the team had designed manually in the past two years. This approach proved to be extremely effective on a number of different levels.

By beginning with very simple designs, the team could get a 'first-draft' of their new tools up and running very quickly. Instead of working for months to develop complex models that could be used for every possible design scenario, team members were quickly able to understand what worked and what didn't. Additionally, the element of 'peer pressure' was introduced to the team – if one team member showed up unprepared for a validation meeting, he or she knew that they would be holding up the entire team. But, by practicing on designs that were familiar to all of the team members, the anxiety of working together in a new process was reduced significantly – the team avoided technical uncertainties and could thus take their time and focus on the group process and their new system-level perspective. Finally, as the team worked through the validation process, their confidence and excitement grew steadily – they were fully energized and more than well prepared by the time they used the new RTCE process on their first real design challenge.

Since the RTCE team was able to focus its work life around a very specific set of tasks, they were able to refine their process over time. The team is currently capable of producing a new product proposal in approximately 30 days (compared to 45 days or more using the traditional approach). Within this time frame, the RTCE team is also now able to compare and contrast approximately 7200 different design parameters between each of ten or more preliminary technical designs in order to arrive at a final design. Using their previous method, they traded 10 to 20 performance characteristics of two or three preliminary ideas before moving on to analyze their final design in detail.

Section 4-C: Deep Dive: Current and Emerging Benefits of RTCE

Between June of 2002 and July of 2003, the author performed a number of surveys of key team members and an extensive set of interviews of team leaders and company managers – including the company President, Chief Technology Officer and three Vice Presidents. In addition, more than ten full-length concurrent design sessions and numerous leadership meetings were witnessed first hand in order to gather observational data on the performance of the RTCE team.

An analysis of these data reveals that the RTCE process has dramatically improved the new product design process at the company. It creates value by increasing the Quality of the company's designs and manufactured products, the Speed at which they are created, by fostering product and process Innovation, and enhancing Learning opportunities.

NOTE: The following findings were based on anecdotal evidence gathered by interview, survey and observation. Refer to Section E of this chapter for quantitative performance metrics.

QUALITY: For each new product proposal, more design options are examined, and each is evaluated far more rigorously. On average, the team examines at least three potential design configurations using the new process. Each conceptual design consists of up to 7,000 standard design variables, which are input, calculated or otherwise determined. Each of these variables is stored in a database, and, because they are common to all designs, competing architectures can be compared directly to one another.

Each designer has continuous access to latest published design variables and assumptions. In the past, weekly design coordination meetings were held to update the team members on important design parameters. In between these meetings, subsystem designers often communicated informally to trade information via e-mail or hallway conversations. Using this ad-hoc information-exchange architecture, however, it was not uncommon for team members to learn that the past week's worth of work had to be completely re-done because of a change made to another subsystem that they were unaware of.

In the new RTCE process, the team discusses details in real-time that could otherwise be overlooked or forgotten. During the course of the validation program and as new designs began to be completed, the team began to notice that there were a substantial number of items that were systematically addressed during each RTCE session that were often neglected in the previous, decomposed design method. They realized that the thoroughness to which each product proposal had previously been completed varied widely depending on the proposal manager and the particular budget or schedule for that project. The team was pleased to set a new and consistent standard of excellence in all of their deliverables.

Key suppliers and manufacturing personnel could be more easily included in the earliest stages of the design. Although the RTCE team has not yet tapped into the huge reservoir of potential design improvements that could be realized by pulling downstream suppliers into the conceptual design process, the modular structure of the RTCE process could easily accommodate their inclusion. Further gains will be made by the elimination of the hard hand-off that occurs between the new product design process and the initiation of the detailed design work done in other departments.

Currently, the detailed design engineers take the proposal generated by the RTCE team as proof that the product can be built, but start the design process from scratch because it is not in a format they can easily build upon and because they do not necessarily trust the output of the proposal team. This disconnect can account for up to 10% of the development time for each new product.

SPEED: In the world of competitive bidding, the reduced lead times for each proposal created by the RTCE process can become a strong competitive advantage. Often, the RTCE team is generating proposals for potential customers that have not completely frozen all of their design criteria. The ability to rapidly incorporate last-minute changes or ideas (without heroic over-time) increases customer satisfaction and allows the team to be the first to set a customer's expectations. As the company negotiates final contracts, the RTCE process has become a competitive advantage – the speed with which the team can incorporate the latest revisions into their proposed design gives the negotiating team more detailed information to share with the customer and more confidence that the proposed design can be turned into real hardware with the time and budget they base their final offer on. And during the negotiations, the fact that the company can now help a new customer rapidly work through a number of "what-if" scenarios as they develop their business plan leads to strategic advantages as well – the company is in a better position to match the needs of their customers with the standard designs that also fit their long-term corporate objectives.

Shorter programs are less expensive. The same number of people working on a team for less time simply saves the company money.

RTCE designs mature more quickly resulting in a program with less uncertainty and rework. Since the team is able to quickly converge upon a conceptual design that consists of up to 7,000 standard design variables, the risk of finding a major flaw in a proposed design is nearly eliminated. As mentioned above, using the previous method, the team often went a week without exchanging vital information. If these meetings were not highly organized, a design that was nearly complete could have to be completely redone because it was based upon false assumptions or incorrect data.

INNOVATION: In its ideal state, the RTCE process focuses on system optimization based on customer value – rather than sub-system optimization based on rigid specifications. The RTCE team has worked hard to develop and validate their worksheet models based on their desire to run smooth, efficient design sessions. In addition, the company has placed its future in the hands of a small number of standard product platforms in order to reduce manufacturing lead-time and cost.

These objectives compete, however, with the process' power to spark innovation based on the system-level visibility afforded to each of the team members. During a session that can include up to 25 participants, it is difficult for one or two designers to take the time to try out a new idea. If an entirely new class of products were to be designed, the current RTCE process would have to be started over from the beginning in order to create a truly innovative new product architecture. Due to the highly complex technical challenges involved, these efforts would have to be supported by a traditional R&D organization, however the work of that group can now be much more closely aligned with the needs of the company and its customers.

Sub-system specialists who may never have worked together have the opportunity to share ideas and seek out new solutions to historical problems – classic organizational barriers are broken. During idle time, the most effective team members will seek out their peers and attempt to work together to constantly improve upon the performance of the system. Many of them finally have the opportunity to see how other subsystems are designed, and to understand the underlying reasons for certain design or interface requirements. In many cases, team members found that requirements that were extremely costly or difficult for them to implement were simply passed down from previous product generations – through the Integrated Concurrent Engineering Process, they were able to ask the right questions of the right people and replace those highly wasteful legacies with innovative new solutions.

Participants take ownership in their process as well as their product. Over time, and with practice, the RTCE team has become highly proficient. They know the capabilities of their system and each other. They are proud to represent their individual functional groups, and have proposed numerous improvements to their process.

LEARNING: The system-level perspective provided by RTCE yields a tremendous viewpoint for each engineer and business staffer to understand the impacts of their decisions and work. Whereas each subsystem specialist used to only concern themselves with the performance of their particular section of the design and would work in isolation from each other, the team members now sit and work together. In addition, the top-level performance metrics are constantly displayed – team members have instant feedback as to the impact their design decisions have on the performance of the overall system.

Dynamic models allow each new team member to "try-out" numerous what-if scenarios quickly and realistically. Due to the parametric nature of the models that the team built, new ideas can be evaluated easily and objectively rather than being shunned by managers who in the past did not have the time or resources to examine them. This new capability has a tremendous impact on the depth of knowledge that team members possess. They now have the opportunity to gain a more intuitive understanding of the system and the interactions of their particular subsystem as well, rather than being analysts who simply run the same set of equations over and over without ever really understanding the alternatives or underlying behavior of the system.

New ideas are evaluated objectively rather than subjectively (opinions based on status or perceived cost). In the past, many ideas put forth by new engineers were also rejected because higher-level engineers or managers already had a mental picture of what the final system would look like. This "design-by-seniority" approach tended to produce products that were all very similar to each other and that always contained the same set of subsystems no matter what. Although this conservative method produced products that were highly reliable and predictable, it discouraged the brightest and most innovative engineers – they tended to get discouraged and sought out more innovative jobs. This not only hurt the company in the short term, but also could have the effect of creating a vacuum of talent that could be particularly damaging when the current group of senior engineers retires in the next few years. The introduction of the RTCE process helps younger engineers raise their voice and show the validity of their ideas in an objective forum. This ability encourages them to continue to introduce new ideas and to be recognized for them.

Section 4-D: Deep Dive: Problems with RTCE

Unfortunately, by the winter of 2002 / 2003, circumstances surrounding the RTCE team were beginning to threaten its performance gains. At the same time the company developed the RTCE project's capabilities, the company's key markets began to sink – customers were delaying orders already in progress and withdrawing from talk of any new contracts. This created tremendous pressure on the RTCE team from all sides. The company experienced a net loss and was forced to lay off nearly 50% of its work force.

Besides the obvious emotional impacts, these circumstances masked the efficiency gains that the RTCE team had fought so hard to win – since people had less total work to do, were uncertain about their future employment prospects and genuinely wanted to help the company win more new business, they spent more time on each individual project than was necessary. By simply measuring the total cost of each new design, the managers were unable to see the improvements made by the team in the efficiency of their conceptual design process. Figure 4-D-1 shows that when the total length of the new product design process was held the same, the savings created by a more efficient preliminary design process were offset by other work. Thus the ROI metric commonly used as a measure to determine if the RTCE team should receive more funding did not reflect favorably on the work of the team.

Aside from these market-related problems, the RTCE team's rapid ascension created some unique and particularly challenging organizational and political problems within the company. These issues must be addressed in order for the team to achieve its ultimate goals, but are also of particular interest to other teams that may be planning to implement a similar real-time concurrent engineering process.

Organizational Structure: Figure 4-D-2 shows the current structure of the RTCE team's company. The manager of the Product Development group initiated the RTCE project, which is a part of the Systems Engineering Division. This was a logical place to implement ICE techniques – this department performed nearly 40 new product proposals each year, so there were tremendous opportunities for process improvement.

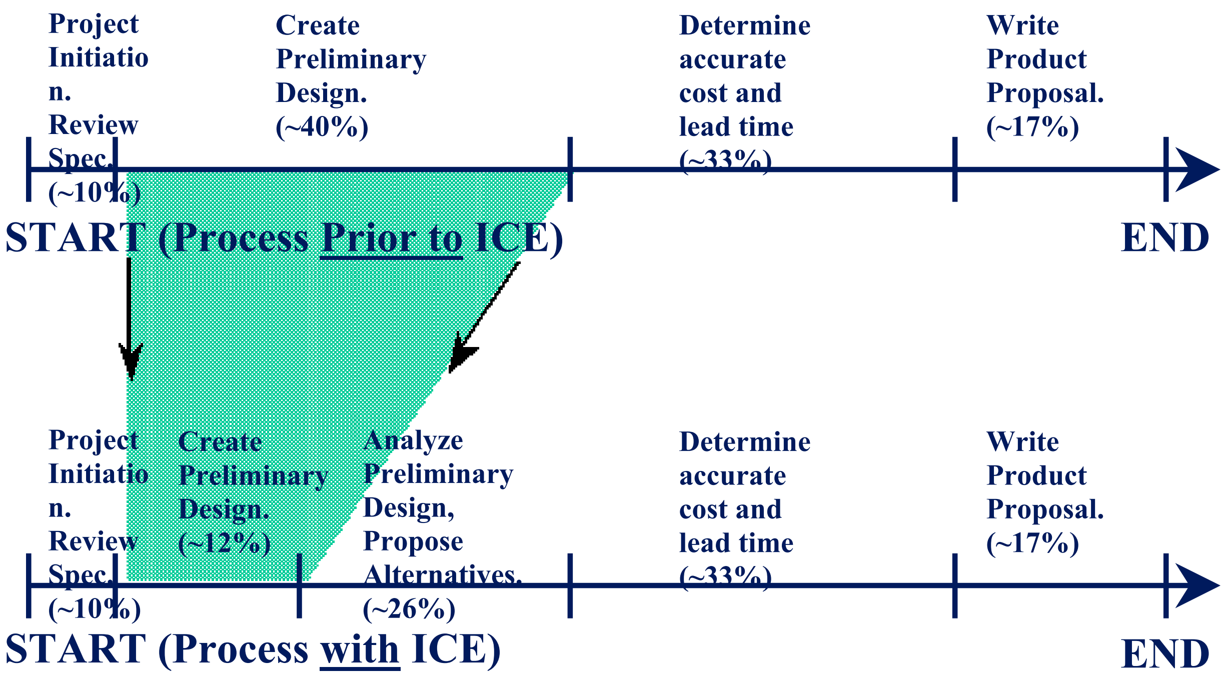


Figure 4-D-1: Timeline of the RTCE Team's typical project prior to and after the implementation of ICE techniques. The team found alternative activities (such as analyzing the design in more detail or proposing and analyzing more design options) to fill the time that was freed by a more efficient preliminary design process.

By June of 2002, all new product proposals were run through the RTCE team and its process. As the impact of their work began to reach other parts of the company however, the team began to encounter some resistance. For example, the marketing group was directly in touch with major customers but was not heavily involved in the development of the RTCE process. Although the RTCE team received detailed product specifications, they often had questions or needed market guidance during their concurrent design sessions. The marketing managers that participated actively in these sessions helped the RTCE team produce superb results. Alternately, some market

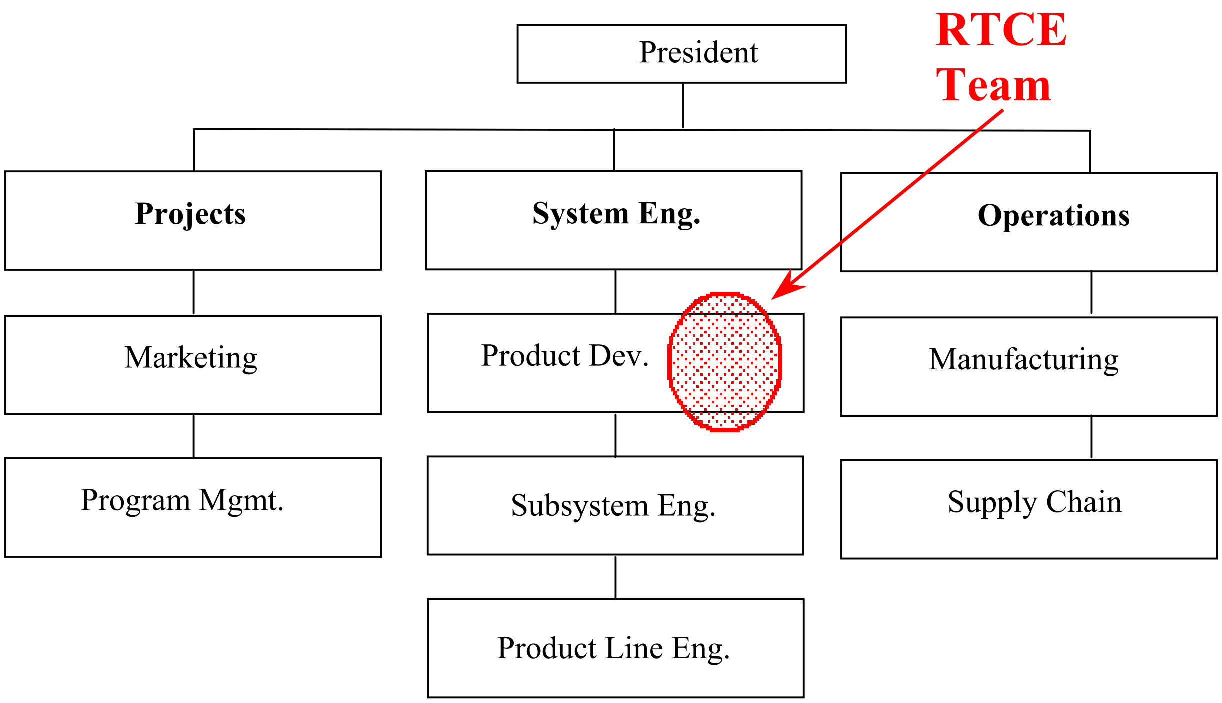


Figure 4-D-2: Organizational Structure of the RTCE Team's Company showing the home department of the team.

managers felt that design sessions were a waste of their time and did not show up for them or left early – this left design engineers frustrated and even led to wasted time and rework.

Similarly, the operations division was only indirectly linked to the RTCE team through one or two team members. This was the result of a scoping decision early on in the RTCE project (the effectiveness of the team began to trail off as the number of participants in a design session grew past about 15 people), but began to negatively impact the company's new product offerings because their input came too late to have dramatic impacts on cost or lead time. Figure 4-D-3 illustrates the effects of the barrier between the RTCE team (who performed the Preliminary Design tasks shown in the bottom third of the diagram) and the Operations group (who performed the Detailed Design and Manufacturing and Test tasks shown in the middle and top thirds). Note that there were other barriers within the operations group as well.

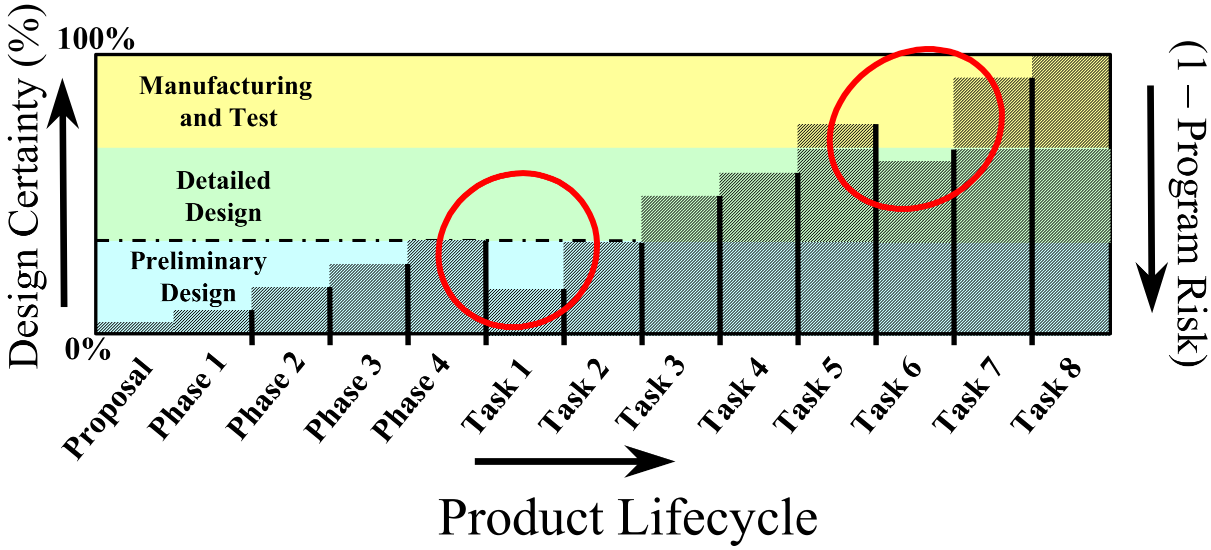


Figure 4-D-3: Notional Diagram of a typical product lifecycle at the RTCE Team's company. Systemic barriers can create large amounts of rework and lengthen the schedule because the information produced in one phase is often not in the form that can be easily used by the next, or work is redone because of mistrust or miscommunication.

One of the long-standing goals of the RTCE team was to implement a "grass-roots" cost model that would allow them to accurately weigh competing design options in real time. In the meantime, the team employed a cost estimation model based on historical data that was adjusted by the team members' estimates of relative complexity. A poll of RTCE team members taken in July and August of 2002 revealed that designers had an average "confidence" in the current cost model of 2.69 (on a scale of 1 to 5). To compensate for this, each proposed design was submitted to the operations group for a detailed cost estimate – an effort that took nearly two weeks and was very expensive.

As mentioned previously, RTCE team members still reported to their functional managers for administrative and evaluation purposes. When the sponsoring manager's overhead budget and the R&D funds began to dwindle, each team member was asked to continue working on their home department's portion of the RTCE project using the overhead accounts of their functional managers. Although several of the team members felt very strongly about the continued success of the project and lobbied their managers successfully, many functional managers were unwilling to support what they perceived as another manager's pet project with their own limited funds. The sponsoring manager responded by inviting the functional managers to participate in a

RTCE design session so they could see first hand the value of the new process – only a small percentage accepted the offer.

Senior Leaders within the company were aware of the organizational issues that were affecting the continued success of the RTCE team, but disagreed about how to proceed. They clearly saw the need to break down barriers between the different divisions but felt that other initiatives would have a more immediate effect on the short-term profitability of the company, and thus shifted more resources to those projects than to the RTCE team.

The RTCE team was also having difficulty prioritizing the issues they faced because they wanted to convey a positive message at all times. They were afraid that if they highlighted the problems, they could risk losing the support they already had. Additionally, it was hard for them to articulate the value of their process in terms of the strict return on investment (ROI) calculations that senior managers insisted on. The RTCE leadership had competing ideas regarding the benefits they had shown and the justifications for continued investment.

Organizational Culture: The shift to real-time concurrent engineering had a dramatic impact on the roles and responsibilities of each team member involved. RTCE team members were initially excited and motivated – many stated that they would never be able to do their jobs in the traditional manner ever again. There was a general euphoria that surrounded an innovative new way of doing business in the first months of the project. Over time, however, technical challenges, market conditions and organizational changes all took their toll on project morale. Interviews with team members elicited the following:

> "I felt that I resolved some on-going questions w/ my counterparts. [The RTCE process] provides a great opportunity for open discussion"

> "Received a good look at the design concept - received really good interaction from [the project manager]"

> "Since I had no schedule input, I felt like I wasted 1 to 2 hours of my time listening to schedule discussions"

> "People were forced to sign up for previous aggressive schedules w/o time to review justifications"

RTCE Team members were also asked to rate the level of participation they felt they had displayed during each concurrent design session (see below). These data revealed that even though RTCE members were doing their work together and sharing information electronically and in the "around-the-room" format, nearly half of them did not behave differently than if they had been working in their own offices.

> 17% said, "Focused only on my client (design spreadsheet)"
>
> 48% said, "Talked to one or two other people"
>
> 26% said, "Solved a minor problem (group of 1 or 2)"
>
> 0% said, "Solved a major problem (group of 3 to 5)"
>
> 4% said, "Helped entire group work through an issue"
>
> 4% said, "Was involved in a major design decision

By the end of the summer of 2002, the growth of the RTCE team passed through many phases and was beginning to impact more company stakeholders than originally anticipated in the team charter. As its boundaries expanded beyond those directly involved, certain perceptions – based on the paradigms of the existing organizational culture – arose:

Myth #1: "RTCE is a great new tool for the company. Once this team is finished developing it, we can deploy it to many other divisions to realize similar gains."

> **Facts:** Each individual toolset is highly customized and serves merely to enhance the effectiveness of each designer – allowing them the freedom to try out new ideas quickly and work together to find innovative solutions to unexpected problems. These toolsets evolve over time, and their strength comes from the fact that they are not just "plug-and-play" spreadsheets. Real-time concurrent engineering is a process – not a technical tool – that is only as powerful as the team running it. To be effective, the team must first learn a new way of working together, define their unique design variables, build and

validate their client models, then practice, learn and adapt. Any team is capable of becoming a high-performing RTCE team, but it will not happen over night.

Myth #2: "RTCE is going to save us tons of money because it automates the design process"

Facts: As one practitioner of ICE put it: "Computers cannot replace people in conceptual design. Rather, a good information system supports human strengths and compensates for human weakness." (Neff and Presley, 2000) One of the company's key strengths throughout its history has been the superb designs its engineers produce. Although Lean concepts and new processes such as ICE can help designers become far more efficient and effective, the need for creative human intuition is actually far more necessary in the new business process than in the old. Attendance at a real-time concurrent engineering design session proves instantly that there is nothing automatic about designing a 100 Million Dollar piece of highly customized technology.

Myth #3: "RTCE is dangerous because it creates 'template engineers' who know nothing about the complex hardware they are designing."

Facts: Fine balances between knowledge re-use and innovation must be drawn and constantly monitored. Although ICE techniques find a great deal of their efficiency in the fact that designers can quickly make use of complex analytical tools and historical databases that were prepared ahead of time, teams have found that the spreadsheets they go into a session with must be as flexible as they are accurate. If a designer enters a real-time concurrent engineering session thinking that his only job is to man his client, then that person might as well not be there. The most powerful solutions come from discussions between different designers regarding a difficult problem, not from a pull-down menu.

Myth #4: "RTCE designs cost just as much as traditional designs – there's no payback for the R&D money we invested."

> **Facts:** The metrics presented in Section 4-E show that the cost of a new product design using the RTCE process is about the same as it was using the previous method. However it has become clear that the quality of the work output by the team is substantially higher. Due to the nature of the process, teams are able to uncover hidden inconsistencies that otherwise would have not been addressed until weeks or months later in the detail design process. In one instance, the RTCE team tested this theory by repeating the design effort of a product they had done using the traditional method. The actual team members and the initial specification were the same – the only difference was the design process employed. The results were dramatic. The RTCE team uncovered a number of major errors and oversights in their initial design.

The increased depth of detail and exploration early on in the design process not only leads to a design with lower risk of technical failure, but also eventually means less work and rework for the detail design team. Applying ICE techniques, concurrent engineering teams now have the opportunity to examine more design options and inspect each one at a higher level of fidelity. The team can then openly and objectively select the best design for the particular customer, and then more easily communicate in a proposal what was chosen and why.

Leadership: Just as the senior management struggled to understand the current and future capabilities of the evolving RTCE team, the team leadership dealt with similar issues of vision and scope. This small group was faced with a number of important decisions and forced to prioritize their own limited resources.

Among the most pressing matters was the roster of the RTCE team itself. As mentioned previously, the original team was composed of the subsystem engineers who had been assigned to the product development center for their technical expertise. Although they represented the most important subsystems, they did not represent all of the specialized functions that were required to complete a final design. They had excelled in positions that allowed them to represent their own functional groups and to coordinate the design activity within their own groups. In the new team however, these individuals were being asked not only to make binding decisions in real time regarding their subsystems, but also to seek out and correct system-level problems that they had never before been exposed to.

The RTCE leadership worked to motivate these team members and to guide the team by expressing their expectations through group and individual "roles and responsibility" statements. Unfortunately, the political and organizational boundaries that separated the team members from the rest of the engineers and technicians who would be doing the detailed design work after a contract was won, could not be overcome by motivation alone. The team was aware that in many cases, after a contract was signed, the detailed designers disregarded their work and began the design process from scratch because they did not understand or trust what was done during the conceptual design process.

But within the team, were the leaders pushing the members to change too quickly, or did they just need to have a fundamentally different type of person assigned to this new job description? One manager suggested that the team should be comprised of younger engineers who were more comfortable working with the complex ICEMaker spreadsheets that had been designed. This team of "learners" would be able to rapidly understand the system they were working on and quickly iterate to a solution that best met the customer's needs for any particular project. Others argued that the team should consist of more experienced, senior experts. This team of "knowers" would be better able to come up with designs that would be robust, manufacturable, and built upon the company's vast history of technical achievements.

The leadership also pondered the outside commitments team members had to their functional managers. How could they expect the team members to think and act with system optimization as a goal when they were going to be evaluated, given raises or even laid off based on the performance evaluation of another manager with a set of priorities centered on optimizing their own subsystem? Unfortunately, the leaders of the product design group spent a majority of their time in meetings and did not take the time to discuss these difficult issues individually with the team members. Although the leaders felt that these were systemic issues that arose from company policy which could not easily be changed, the fact that these issues went un-discussed caused a great deal of anxiety and frustration among team members.

Next, the RTCE leadership had to decide how to obtain more funding for their program and where it could be applied most effectively. There were clear differences of opinion in this arena, and the sponsoring manager tried to give the team leaders the autonomy to make a decision based on their own vision, however without clear authority given to one member decisive action was not easily taken. One side advocated strongly to add CAD modeling capabilities so that team members could visualize complex assemblies and create more complete designs during each session. This effort would involve subcontractors creating libraries of standard parts – an expensive and lengthy proposition, but one that could add great strength to the team. Others desired improvements to the cost modeling or additional functionality for each subsystem client. Each option needed to have its cost and return on investment estimated in good detail.

Finally, the RTCE leadership wanted to measure its progress using metrics. They hoped that an analysis of labor hours spent, design completeness or the number of options examined would provide conclusive evidence of their positive impacts on the company. The initial data were inconclusive, however. It showed that the potential value RTCE could add to the company could only be realized by increasing the scope of the process – beyond preliminary design and into detail design work and manufacturing. The team leadership used these metrics as aids in decision-making however and did not attempt to set targets so that the RTCE team could monitor its achievements on a continuous basis.

Financial: The last major category of organizational issues that the RTCE team encountered involved money. As mentioned above, internal R&D funding was limited due to the market conditions and the financial position of the company. Although the bold move taken by the sponsoring manager to charge initial work to his overhead account had paid for itself handsomely in the form of a fully functional and valueadding process, more work needed to be done. Some members of the team felt that substantial expenditures were required to achieve the goals they had laid out. Others felt that a great deal of progress could be made using a "coordinated-individuals" approach – having people work on process-improvement as they performed value-added work for each new project. Were there contributions that could be made by team members in their spare time? In the spirit of real-time concurrent engineering, wouldn't working team feedback / continuous improvement meetings a much more effective approach to the teams near term challenges than a centralized, rigid task list?

Personal and organizational incentives also played a large role in the actions of the RTCE team. The company operated under a system whereby R&D investments would be repaid over time by decreases in a department's allocated budget based on the projected savings of the projects that received funding. So, if for example, the RTCE team stated in a proposal that an investment of one million dollars would result in a 5% productivity improvement, the product development department would have their budget reduced by 5% the next year. This system was intended to instill a degree of fiscal discipline into the company, however managers were rarely on the lookout for projects that would result in their budgets being cut, especially if that meant they would have to lay off their employees as a result.

When an RTCE project came down to final pricing, the team always faced another handicap. Even though the team had developed some cost models that could be used to make rough-order-of-magnitude (ROM) estimates in real-time during the session (and validated their models to within a few percent), a formal costing effort would always follow their work. Due to company tradition, and in the absence of another sanctioned method, all new prices were based on historical prices. Once the team completed its technical proposal, it would be forwarded to most of the functional managers for cost estimating. Each would examine the relative complexity of the proposed project as compared to past projects. Some would then add in charges for new special projects they wanted to use the new program to pay for, and would add in their own padding to ensure that their department did not go over budget. A special cost team (separate from the RTCE team) would then collect all of the cost estimates, roll them together, apply the corporate overhead rates and mandatory profit contribution, and then present a final cost to the executive management. Because the conceptual designers were not involved in this process, and due to the manual process of communicating the design details and cost items, the cost that was calculated could be for a different design that the one actually being proposed. A special review board would then review the cost, the company's strategic and competitive position, and then recommend a price that would be offered to the potential customer. Using this method, the company was completely unable to match the reductions in price that their competitors were beginning to offer – they were unable to estimate and account for the potential savings that would be made due to the higher quality designs that the RTCE team had produced.

Lastly, the accounting system employed by this company (and all others who performed work for the Department of Defense), mandated strict enforcement of timekeeping and charge numbers. Employees were audited periodically to make sure that the time they spent at work was charged to the appropriate accounts. Once the R&D money for the RTCE project was depleted, this meant, in effect, that many employees sat idle or stretched minor tasks for other programs that were funded instead of working efficiently on both other work and RTCE. Team members were actually dis-incentivised from using their spare time to work on RTCE or help out fellow team members because they did not have a charge number to reconcile their work with. The implications for this system should be immediately apparent to any manager and were extremely disheartening to the RTCE team leaders.

Section 4-E: Deep Dive: RTCE Metrics

Despite the organizational impediments that have slowed the progress of the RTCE team, they have been able to show tremendous success in their first crucial year of operation. Since the RTCE process became the standard new product design process in March of 2002, the team completed at least 10 new product proposals. They have trimmed 33% of the lead time from their standard process, and are now capable of creating new designs in as little as 4 hours – compared to up to 4 weeks previously. The designs they do produce are of higher quality because they examine each option in greater detail earlier in the design process by sharing thousands of design variables in real time. The team also enjoyed very high morale early in its formation.

Over the course of this project, the author collected performance data on nearly 100 new product proposal projects. Due to inconsistencies in the data or missing data items, the list was reduced to 43 final project sets. These projects were sorted according to the project scope. A subset of 36 of these projects – those classified as "Major Projects" – were further classified into following categories: year, use of RTCE and the number of designs considered. In order to provide additional context, personnel data were obtained to determine the number of employees working on these projects at any given time. The following table provides definitions of the key terms used in the process metrics provided below.

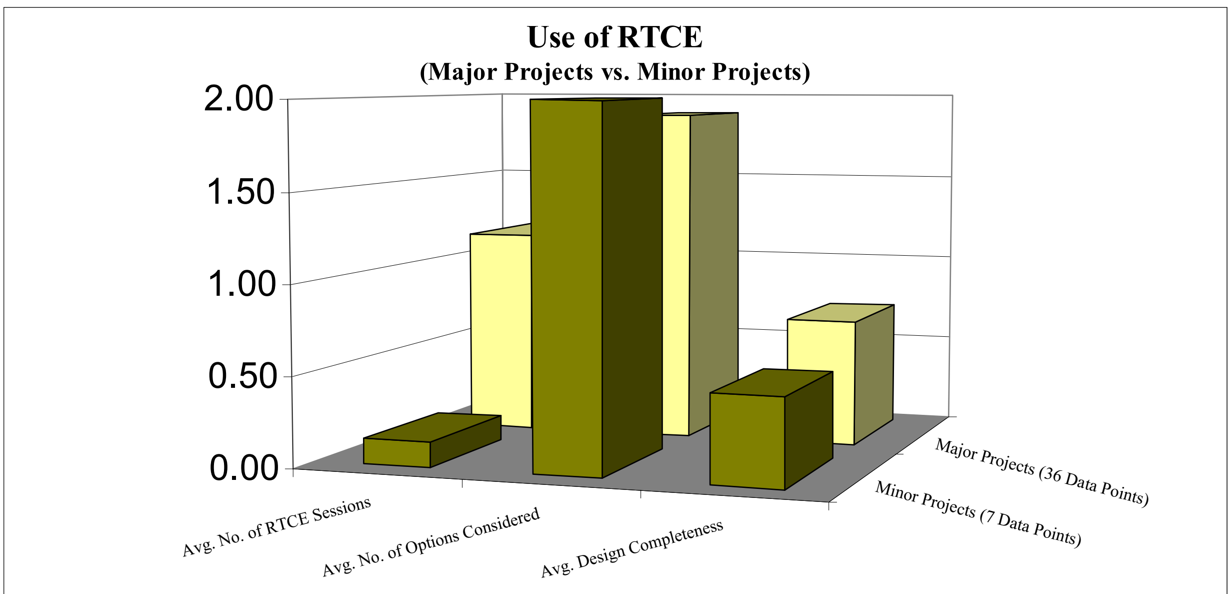
Definition of RTCE METRICS (Term: Definition)
Major Project: Formal proposal projects that begins with an official specification from a potential customer and results in the offering of a "Firm, Fixed Price" proposal for a highly refined new design.
Minor Project: A less formal response to a customer's inquiry. In response to a general, somewhat flexible set of initial requirements, the team submits a "Rough Order of Magnitude" (ROM) estimated price and one or more design concepts.
Without RTCE: This label refers to projects that were completed without the use of the Real Time Concurrent Engineering process.
With RTCE: This label refers to projects that included one or more Real Time Concurrent Engineering sessions in order to perform conceptual design work. This label does not eliminate the possibility that some design work was done using the traditional decomposition method.
Point Design: This label refers to projects that examined only one design architecture in detail. Although it does not exclude preliminary brainstorming sessions in which a number of potential ideas are discussed, in this scenario, the team chose one design option to pursue generally within the first week of the project.
Multiple Trades: This label refers to projects that examined two or more design options in significant detail. In most cases, these designs were presented either to the company's executive management, to the customer, or both.

Definition of RTCE METRICS (Term: Definition)
Projects: This staffing category represents direct hours billed for work on a specific design project (either a Major or Minor project as defined above).
Technology / Process Improvement: Any activity that was funded by corporate R&D money. This included development of new hardware and software for the company's products as well as new business processes such as RTCE.
Management / Overhead: All time spent on supervisory, support or special projects. As mentioned previously, between November of 2001 and March of 2002, half of the development of the RTCE process was charged as "overhead" in order to stimulate the project and make up for a lack of R&D money.
Average Number of RTCE Sessions: This label describes the average number of RTCE design sessions that were completed as a part of each project. Projects that did not employ the RTCE process, by definition have zero sessions.
Average Number of Options Considered: This category describes the average number of options considered for projects that had Multiple Trades as defined above.
Average Completeness Index: In the RTCE's home department, a set of standard tasks was to be completed for each new project (regardless of Major or Minor classification). These tasks were grouped and weighted according to their relative importance. At designated project milestones, the progress of the team was compared to the standard task list, and a project completeness index was calculated. The index ranged from 0 to 1 with a score of 1 signaling that 100% of the required tasks had been completed on the project in question. (It should be noted that many new projects deliberately planned for completeness index scores of less than 1 in order to save money or time. Alternately, many projects completed additional tasks that consumed project resources but did not increase the completeness index score.) These numbers were then averaged across each project category.
Average Index Cost: The cost of each project was obtained from the finance department. In order to protect proprietary information, the costs were all normalized. Thus an index cost of 1 represents the most expensive project undertaken by the group, and a score of less than 1 represents cost of each project as a percentage of the most expensive project. These numbers were then averaged across each project category. As a complete set, the average project cost index was 0.26.
Average Cost per Option: For each of the projects, the cost index number described above was divided by the number of design options that the project team considered (according to the definitions of Point Designs and Multiple Trades described above) in order to determine a secondary measure of productivity. These numbers were then averaged across each project category.

Definition of RTCE METRICS (Term: Definition)
Average Cost per Completeness: For each of the projects, the cost index number was divided by the completeness index in order to determine a measure of process efficiency. These numbers were then averaged across each project category.
Total Dollars: This number represents the total expense of a new product design project, it is the sum of costs that are assigned to the following categories: "design dollars," "cost dollars," "management dollars," as well as an overhead, or "G&A" charge.
Productivity: This metric is a generalized measure of the value-added work being accomplished within the RTCE's department. Monthly productivity is calculated by taking the total number of normalized project units (where each Minor project completed counts for one unit and each Major project completed counts for five units) and dividing by the average total staff level that charged their time to the "project" category.

Project Scope Metrics

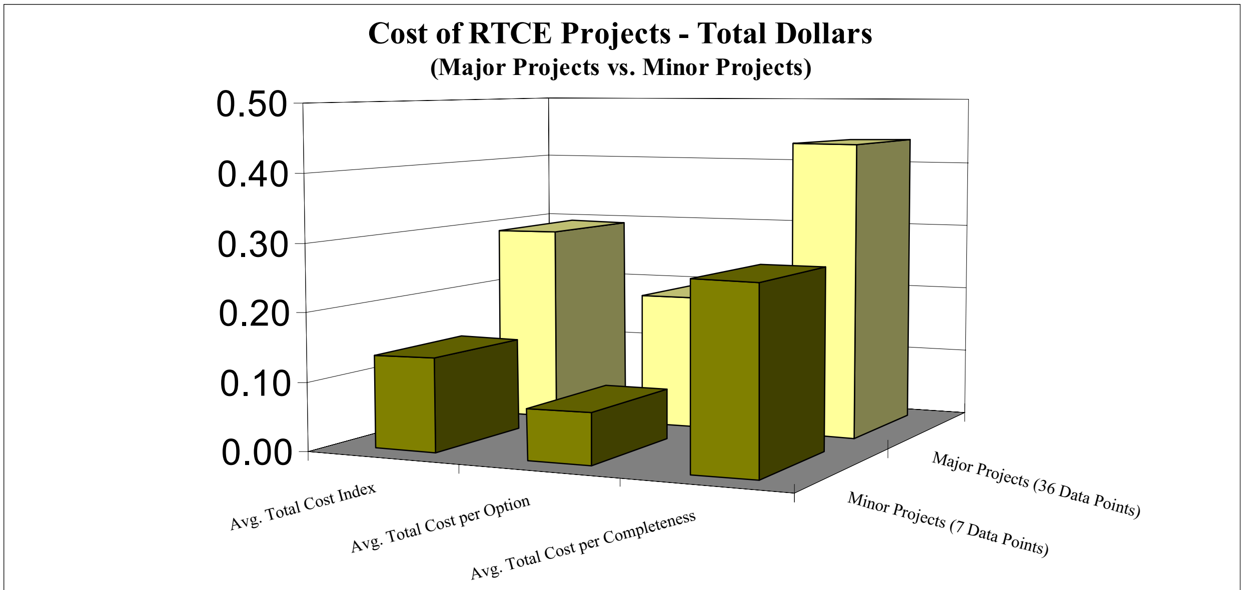
The data presented in Figure 4-E-1 comparing the process steps followed by both Major and Minor projects seem consistent with expectations. Major projects employed



	Avg. No. of RTCE Sessions	Avg. No. of Options Considered	Avg. Design Completeness
Minor Projects (7 Data Points)	0.14	2.00	0.49
Major Projects (36 Data Points)	1.17	1.89	0.72

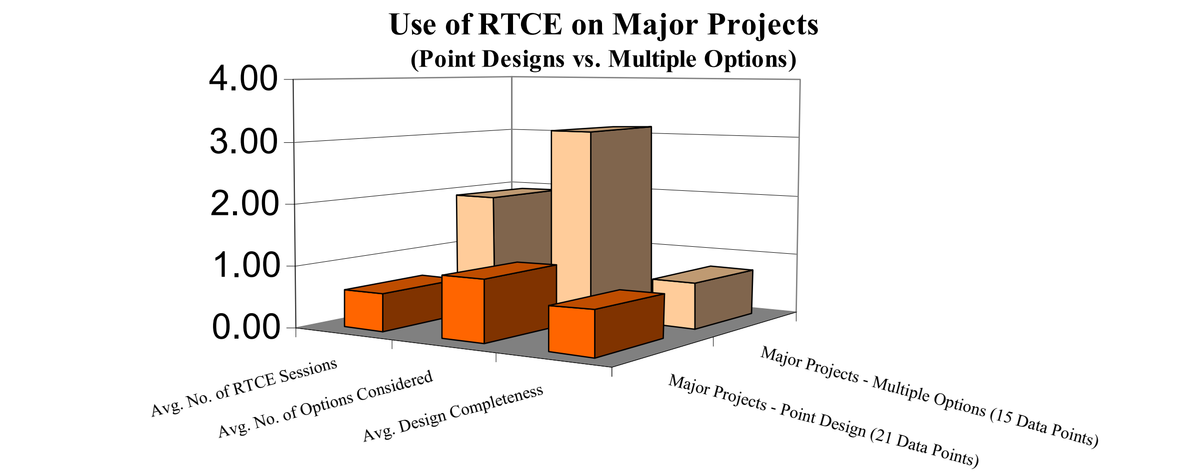
Figure 4-E-1: Use of RTCE – Comparison of the average number of Design Sessions, the average number of Design Options considered and the average Design Completeness Index between Major and Minor Projects.

more RTCE design sessions because they needed to examine design architectures in greater detail. However, Minor projects considered more design options because of their less formal project deliverables – it was easier for them to carry more options forward because the amount of work required to present an option was far less than the formal cost, schedule and technical proposals that were required for each Major Design Trade. Often, potential customers use the Minor projects to help shape their business plans, so they actually request to see more design options. On Major projects, customers may send the same requirements to many potential suppliers and usually accept only one design option with each proposal so that they can very clearly compare one supplier's offering to another. Also as expected, Minor projects had lower average costs, costs per option and costs per completeness indices. This trend can be attributed to the less stringent demands on the quality and depth of each design option that Minor project teams presented to each customer. Refer to Figure 4-E-2 for these data.



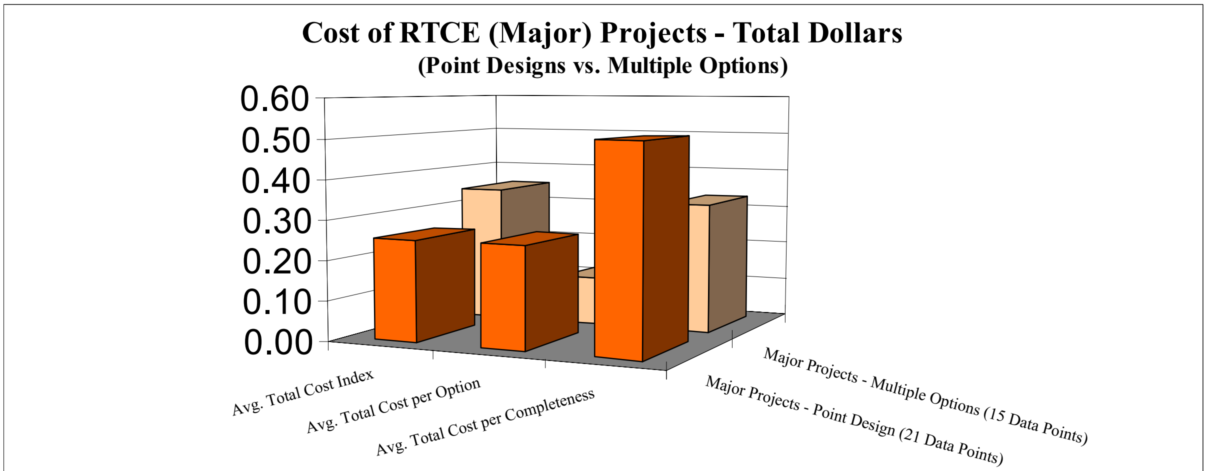
	Avg. Total Cost Index	Avg. Total Cost per Option	Avg. Total Cost per Completeness
Minor Projects (7 Data Points)	0.14	0.07	0.27
Major Projects (36 Data Points)	0.29	0.20	0.44

Figure 4-E-2: Cost of RTCE Projects – Comparison of the average Index Cost, the average Cost per Option and the average Cost per Completeness between Major and Minor Projects



	Avg. No. of RTCE Sessions	Avg. No. of Options Considered	Avg. Design Completeness
Major Projects - Point Design (21 Data Points)	0.62	1.00	0.70
Major Projects - Multiple Options (15 Data Points)	1.93	3.13	0.74

Figure 4-E-3: Use of RTCE on Major Projects – Comparison of the average number of Design Sessions, the average number of Design Options considered and the average Design Completeness Index between Major projects that examined only one design option (a point design) and those that explored multiple options



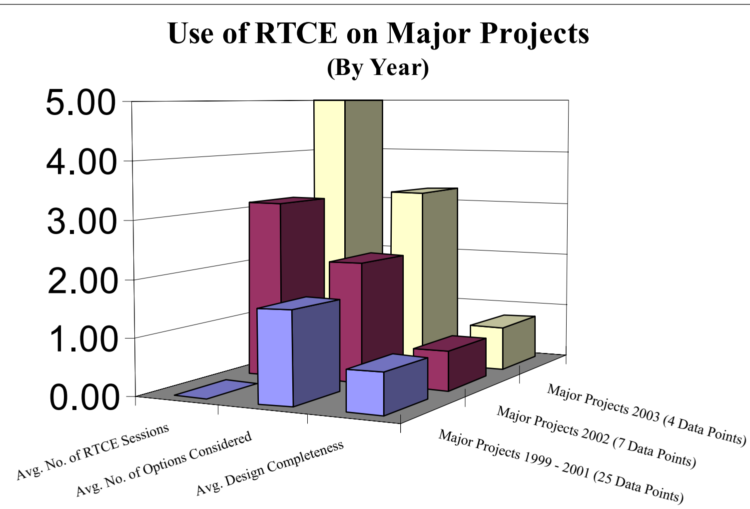
	Avg. Total Cost Index	Avg. Total Cost per Option	Avg. Total Cost per Completeness
Major Projects - Point Design (21 Data Points)	0.25	0.25	0.51
Major Projects - Multiple Options (15 Data Points)	0.35	0.12	0.33

Figure 4-E-4: Cost of RTCE Projects – Comparison of the average Index Cost, the average Cost per Option and the average Cost per Completeness between Major projects that examined only one design option (a point design) and projects that explored multiple options

Number of Options

Figures 4-E-3 and 4-E-4 compare the performance of teams that followed the "point-design paradigm" identified in Chapter 1 with those that took the extra time to examine multiple design options. Design teams that aggressively pursued more options in order to provide their customers with additional perspective or higher quality choices, were able to more than triple the number of options they were able to examine in detail while increasing their costs by an average of 40 percent. This non-linear efficiency gain shows the power of working together in real time.

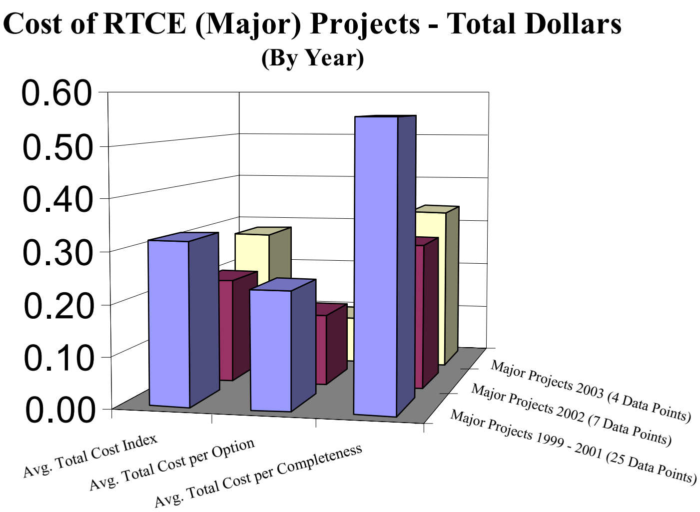
Project Metrics by Date



	Avg. No. of RTCE Sessions	Avg. No. of Options Considered	Avg. Design Completeness
Major Projects 1999 - 2001 (25 Data Points)	0.00	1.60	0.71
Major Projects 2002 (7 Data Points)	3.14	2.14	0.70
Major Projects 2003 (4 Data Points)	5.00	3.25	0.79

Figure 4-E-5: Use of RTCE on Major Projects – Comparison of the average number of Design Sessions, the average number of Design Options considered and the average Design Completeness Index for Major projects completed in 1999-2001, 2002, and 2003

As the skills and acceptance of the RTCE team grew, so too did the average number of design sessions each project utilized. Figure 4-E-5 shows the increasing use of the RTCE process on Major Projects over time. As the team's efficiency grew and project managers began to understand the power of the new process, the average number of options considered by each project team increased. Additionally, as the RTCE process came through development and into full-scale implementation, the average completeness index of each new project climbed.



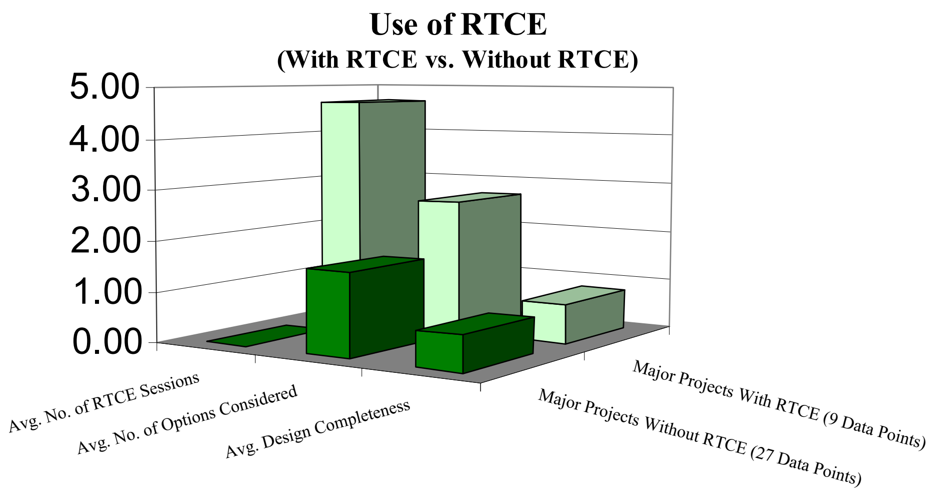
	Avg. Total Cost Index	Avg. Total Cost per Option	Avg. Total Cost per Completeness
Major Projects 1999 - 2001 (25 Data Points)	0.32	0.23	0.56
Major Projects 2002 (7 Data Points)	0.21	0.14	0.29
Major Projects 2003 (4 Data Points)	0.28	0.10	0.34

Figure 4-E-6: Cost of RTCE Projects – Comparison of the average Index Cost, the average Cost per Option and the average Cost per Completeness for Major projects completed in 1999-2001, 2002, and 2003

In terms of efficiency, Figure 4-E-6 shows that some of the gains made by the RTCE team have been slightly eroded in 2003. However, the new product development group is still performing better than it was in the 1999-2001 time frame. These data clearly show reductions in the average cost of each project, the cost per design option, and the cost per completeness index. These trends validate all of the effort that the RTCE team has contributed despite numerous structural, cultural, leadership and financial roadblocks. If these issues were to be adequately addressed, the results would be even more dramatic.

The fact that the 2003 projects were slightly more expensive and less efficient than in 2002 is in line with the observations noted at the beginning of Section 4-D. There, it was stated that many of the new improvements made possible by the RTCE process were partially masked by the market and organizational pressures that surrounded the team. Team members used additional time during the design process to do extra analysis in order to improve the quality of the proposed designs and in order to keep busy as their workload tapered off.

RTCE Use



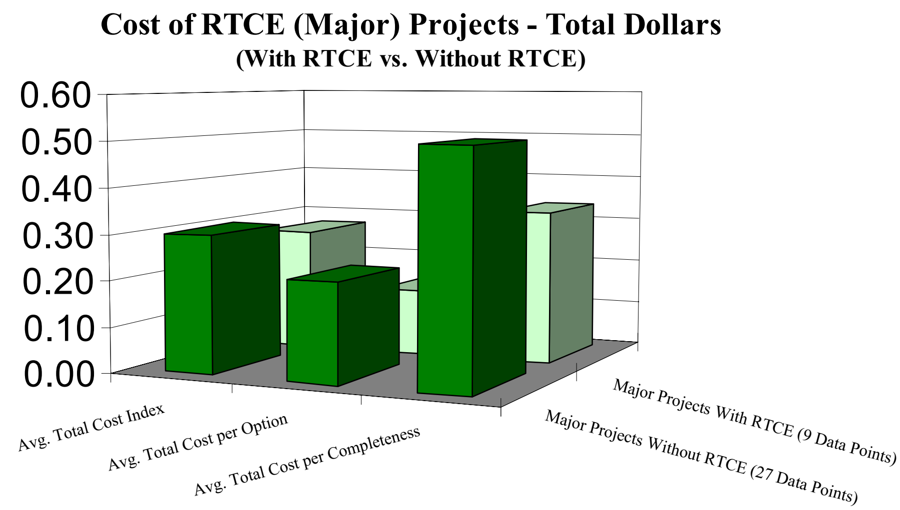
	Avg. No. of RTCE Sessions	Avg. No. of Options Considered	Avg. Design Completeness
Major Projects Without RTCE (27 Data Points)	0.00	1.63	0.68
Major Projects With RTCE (9 Data Points)	4.67	2.67	0.78

Figure 4-E-7: RTCE Use – Comparison of the average number of Design Sessions, the average number of Design Options considered and the average Design Completeness Index for Major projects that used or did not use the RTCE Process

As shown in Figure 4-E-7, project teams have clearly taken advantage of the power of the new RTCE process. On average, they now examine more design options per project, and also work on each one in greater detail.

As Figure 4-E-8 identifies, since the average total cost of a Major Project has been kept about the same, the RTCE process is clearly more efficient than the traditional method as measured by the cost per option and cost per completeness index metrics.

In the case of the RTCE team, all projects have due dates that are set by the needs of the customers, and the average length of a project has not changed much over the past few years. The efficiency gains noted above now mean that the team can accomplish more within the same time frames they have always been given. Instead of using the time to examine one design option in great detail, teams can now look at a few designs during the same time frame and actually go into more detail on each.



	Avg. Total Cost Index	Avg. Total Cost per Option	Avg. Total Cost per Completeness
Major Projects Without RTCE (27 Data Points)	0.30	0.22	0.50
Major Projects With RTCE (9 Data Points)	0.27	0.15	0.34

Figure 4-E-8: RTCE Use – Comparison of the average Index Cost, the average Cost per Option and the average Cost per Completeness for Major projects that used or did not use the RTCE Process

As the RTCE process becomes more mature, the team members more confident, and the project managers more comfortable, the team expects costs per project to decrease steadily over the next few years. New projects are being planned more deliberately, and holding to more fiscal discipline. Whereas in the past, the team just worked as hard as they could to complete a given proposal by the specified due date, the RTCE team now offers a standard "menu" of tasks with predictable prices and lead times. Based on the available budget for any given project, the project manager and the RTCE team can negotiate in advance a list of specific tasks or a level of design Completeness that will be achieved. Later on during a project, items can be either added or removed according to the specifics of a situation without complaints of budget-overruns or team under-performance.

Eventually, as these projects move into the detailed design and production phases, the RTCE team believes that the increased completeness they were able to examine will result in reduced cost and risk throughout the product lifecycle. Using RTCE, they are able to uncover and solve problems early in the conceptual design phase that may not otherwise show up until much later.

Staffing

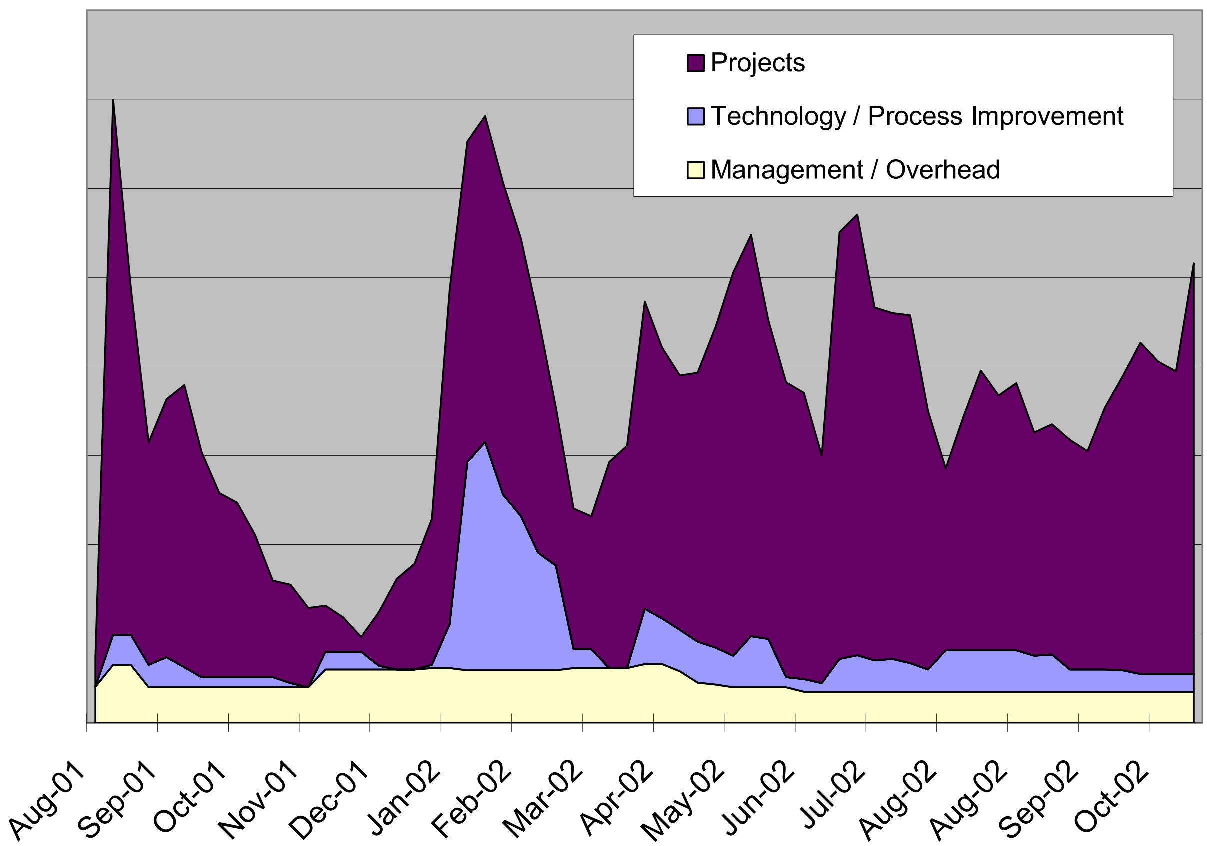
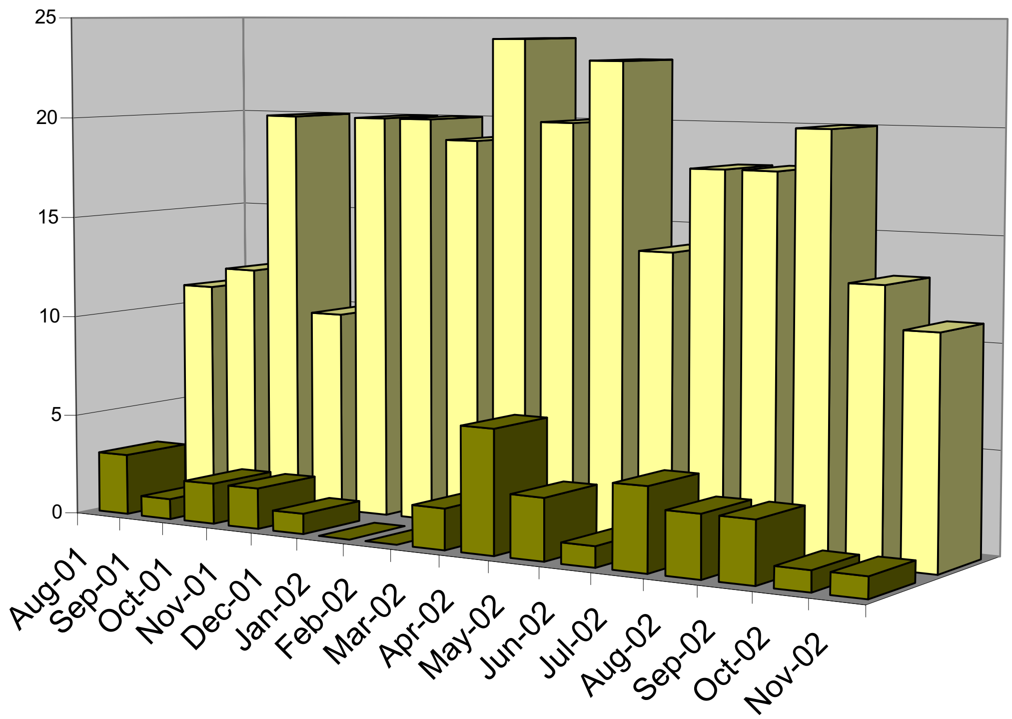


Figure 4-E-9: Staffing – "Equivalent Headcount" (number of 40-hour-weeks billed each calendar week) of projects originating in the Product Development Group of the RTCE Team's company. Hours charged were grouped into categories by the nature of work performed.

Figure 4-E-9 shows the total relative staffing levels, or "equivalent personnel" in the Product Development group (the home department of the RTCE process team). The source of the data is the company's time card database, which records the hours charged by each person to each task. In order to protect proprietary data, the units have been removed from the graph. The most important observation is the highly cyclical nature of the volume of work performed by this department. Much of this pattern is driven by the demands of the company's customers. The initial development and validation of the RTCE process accounts for the large spike in the "technology / process improvement" category between January and March 2002 and the increased level of "management / overhead" spending between November of 2001 and April of 2002.

When projects are under deadline, team members often work 50 or 60 hours a week (a rate of 1.25 to 1.5 "equivalent personnel" on the graph above). Additionally, specialists may be brought in from other functional groups to assist on large projects. Likewise, when there are fewer proposals due, the staff of the product development group often fills their time by working for their individual functional managers – charges that would show up in a separate projects category from the one shown above. This arrangement can cause prioritization problems however. If a team member has committed to a project for his functional manager during a lull and an unexpected proposal project arises, scheduling conflicts cannot be avoided.

Figure 4-E-10above shows the total number of Major and Minor projects completed by the product development group. The projects that utilized the RTCE process are a subset of these projects.

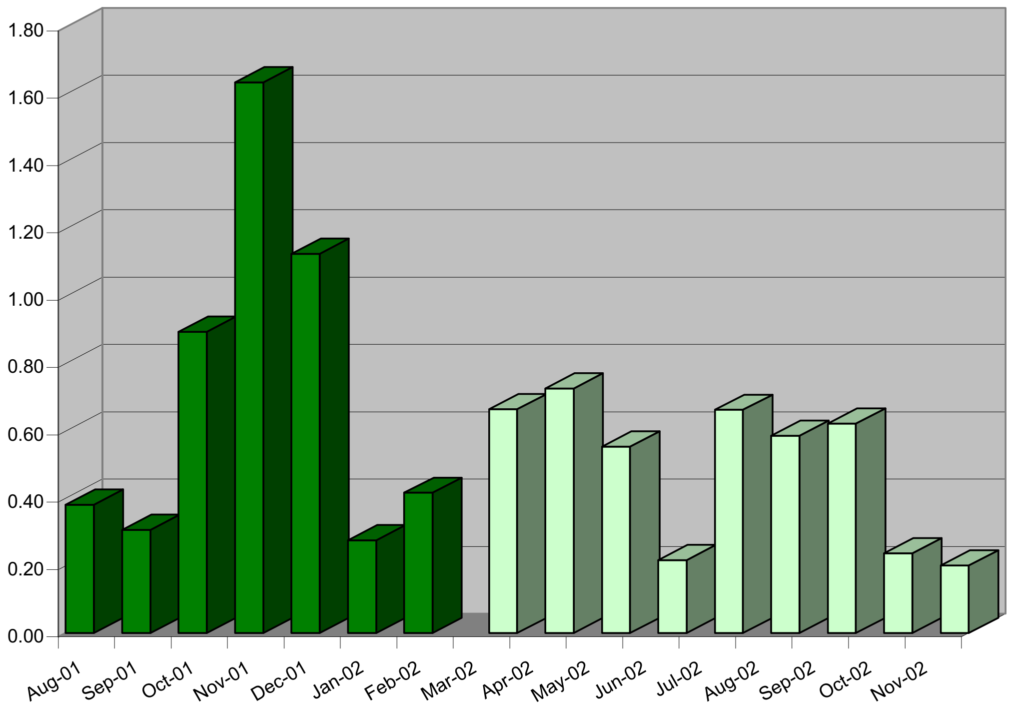


	A-01	S-01	O-01	N-01	D-01	J-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02
Major Projects	3	1	2	2	1	0	0	2	6	3	1	4	3	3	1	1
Minor Projects	11	12	20	10	20	20	19	24	20	23	14	18	18	20	13	11

Figure 4-E-10: Work Load – The number of projects completed by the Product Development Group of the RTCE Team's company, grouped by the month each was completed.

Finally, as defined in the table at the beginning of this section, the Figure above shows the relative productivity of the product development group before and after the implementation of RTCE. The average score prior to the implementation was 0.72, and afterwards was 0.50. These data indicate that, on average, after the RTCE process was implemented, productivity actually decreased, however there may be more than one explanation for this observation.

The most important driver of this difference was the extremely low level of staff hours charged between October and December of 2001. During this time, the author may have been unable to obtain complete data, or an accounting error occurred – some of the projects "completed" during those months may have been in-process for quite some time and thus the hours charged were not properly matched to the time frame that the project was booked as complete.



	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02
Without RTCE	0.38	0.31	0.89	1.64	1.13	0.28	0.42									
With RTCE								0.66	0.73	0.55	0.22	0.66	0.59	0.62	0.24	0.20

Figure 4-E-11: "Productivity" of the Product Development Group of the RTCE Team's company. This metric is a generalized measure of the value-added work being accomplished within the department. It is calculated by taking the total number of project units for each month and dividing by the average total staff level that charged their time to the "project" category in Figure 4-E-10.

Next, the time period represented by the data may not long enough to show the actual trend. The initial months of RTCE implementation were a time of learning and experimentation – the team took their time to build a robust tool and often encountered setbacks. In the long run, the leadership of the RTCE team was confident that the productivity metric would show positive improvements.

However, as explained previously, the productivity, or Return on Investment, metric should not be the overarching measure of the success of the RTCE team. The increased quality, speed, accuracy, innovation and learning opportunities provided by the RTCE process will have profound benefits on the entire product lifecycle resulting in products that deliver more value to customers and present less technical and financial risk to the company.

Summary of RTCE Team Metrics

On average, in their first year RTCE projects cost 10% less than traditional projects. Although this was not the radical savings the team leaders had initially hoped for, the team firmly believes that their costs will drop steadily as they continue to learn and improve their process. It is still too early to calculate a traditional return on investment (ROI) metric for the savings generated by the RTCE process. However, the investment did purchase the following:

- On average, using RTCE, each new product design project was able to consider 64 percent more design options.
- Each option is examined to 15 percent more detail.
- As measured by both the cost per option and cost per completeness metrics, the RTCE team was 32 percent more productive than they had previously been.

As the first few projects that used the RTCE process move into production over the next two years, the team is completely confident that the data will reveal that their ability to examine more designs in greater detail early in the conceptual design process will result in production programs that yield higher quality products that can be repeatedly manufactured on-time and on-budget.

Section 4-F: Deep Dive: Implementation of MATE-CON

During the summer of 2002, the addition of a trade-tool capability was proposed to the RTCE team leadership. The concept was intended to enable the RTCE team to perform the following functions:

- Capture and prioritize customer preferences
- Target regions of the potential design-space for closer examination

- Objectively compare one proposed design to another
- Easily and objectively compare a proposed new design to past products the company had successfully produced
- Keep track of small iterations off of a proposed design, and evaluate if each was better or worse than the baseline
- Evaluate a proposed design versus the best estimates of what know competitors would offer to the customer
- Communicate in one visual graphic to managers and customers:
- Communicate why a proposed design was chosen
- Communicate how proposed designs were evaluated
- Analyze and communicate the strengths and weaknesses of proposed designs, and determine how much it would cost in terms of time and money to eliminate each of the weaknesses

The MATE-CON process described in Chapter 3 was proposed as a method of providing the above functions to the RTCE team. Unfortunately, the process has still not been implemented due to a number of technical and cultural issues.

One team leader in particular was extremely enthusiastic about the use of MATE-CON. Almost immediately after it was proposed, however, he struggled to find appropriate attributes of the systems that the team designed. In particular, the team typically had three of four high-level requirements that could easily be turned into attributes – the trade-offs between these were already well understood, however. The real need arose when the team traded off second-tier requirements, of which there were typically between 20 and 40. Since the current MATE-CON process can only accommodate up to seven attributes simultaneously, this situation presented a problem to the implementation leader. A number of creative groupings were proposed, but in dong so, the team would lose the ability to actually trade between the different parameters. Additionally, going through the MATE-CON utility interview for a large number of attributes was time and reason-prohibitive. It was just too difficult to estimate the value of certain hypothetical systems, and the probability of success of each proposal.

Second, the team had a large disconnect between their design process and their potential customers. The nature of the industry they were in was heavily dependent on a competitive bidding process that prevented open communication between the company and a customer during the proposal process. Typically, one senior manager was assigned as the company's representative to the customer. MATE-CON was presented to several of them, but not one ever requested additional information or a more detailed explanation. Most thought it was too complicated and completely unnecessary. The customer representatives believed that they provided all the information that the design team could possibly need. This was untrue in a few cases, although most of the customer representatives did not attend the concurrent design sessions or left "after their part was done." This frustrated the design team because they often had to make difficult choices based solely on their own guesses about what a customer might want, or were forced to do two or three complete designs in order to have the representative choose one that might be presented to the customer.

Third, in order to compare new proposals to existing designs using MATE-CON, the team needed to access to historical data for all of the chosen attributes. The data were utterly unavailable to any team member. No centralized data storehouse was maintained, and most project managers kept their own files according to what they thought was important, often leaving large pieces of information incomplete when they transferred to other divisions, left the company, or were laid off. An extensive search of all available records was undertaken (totaling more than a month of the author's time), but not enough information was located to complete the project.

Finally, even if the team had wanted to implement the new process, the RTCE team was not given the time or resources to develop a stand-alone MATE-CON tool that could be integrated into a design session, nor did they have the ability to assign a team member to operate it during a session. This, and the database project mentioned above, were not the only areas of potential improvement that were picked up, then neglected again and again by team members who volunteered to try them out in their free time but simply did not have enough time or motivation to see them through.

The following is a summary of the lessons learned when the RTCE team attempted to implement the MATE-CON process:

- True customer collaboration is essential – this requires cooperation between designers, managers, sales and marketing people, and the customers themselves.
- Trying to implement a new system is a risk, and many people will be afraid to try new ideas because they are threatened by them.
- Defining MATE-CON Attributes is labor intensive and requires skill and patience
- The Utility Interview (which determines the utility curves used in a MATE-CON analysis) is difficult and elicits the voice of only one key decision-maker at a time
- Modeling the system at an appropriate level of detail takes discipline and coordination
- Parametric Models are difficult to construct
- Need to incorporate error-checking and limits with closed form solutions in the models
- Challenge: How to model systems that have never been tried before
- Cost Models can be very influential
- The basis for the models will drive your design – make sure you agree with the underlying assumptions
- If you base new costs on historical costs, you may never achieve new innovations
- MATE-CON is intended to be an iterative process
- Users should maintain an open line of communication with key decision-makers and validate output continuously
- Don't waste time in the beginning trying to make perfect models
- Go for a uniform accuracy target (+/- 5%) at first, then hone in on the important areas of the tradespace and improve your models

Section 4-G: Strategies for Near Term Re-Vitalization of the RTCE Team

As is the case at most aerospace companies, when it comes to project implementations, the strong engineering heritage of the company guides the organization along the most comfortable path: technology. Engineers – and managers who were once engineers – are fantastic problem solvers. When faced with the challenges listed above, the RTCE team reacted in the way they were trained and rewarded for acting throughout their careers – by proposing and implementing strong technical solutions to the most tangible problems, and leaving the rest for another day.

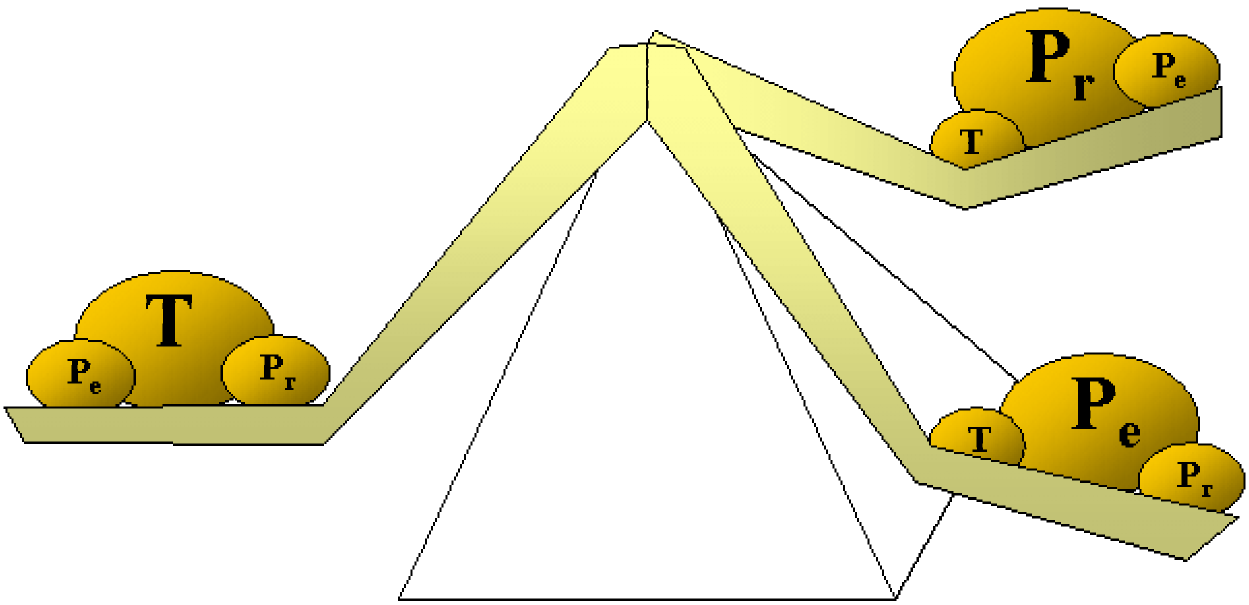


Figure 4-G-1: The "TPP" Model shows the interaction of the "Technology (T)," "People (Pe)," and "Process (Pr)" issues that dominate any project implementation. All three areas must be addressed in proportion in order to achieve process harmony. Actions taken in each category help the efforts in other categories to become more effective.

Through observation and collaboration, the author is proposing a new model through which the positive achievements and the potentially damaging issues delineated in the previous sections can be highlighted and addressed. Figure 4-G-1 shows a pictorial representation of the careful balance that must be struck between Technology, People and Process in order for any project to be successfully implemented. A similar framework was proposed by (Neff and Presley, 2000), after the implementation of a similar team at the Aerospace Corporation As the RTCE team learned first hand, regardless of the potential value that a new innovation can create, the implementation team must examine and solve problems in all three categories. If a team focuses disproportionately on the technical challenges, the project will encounter people and process issues that will impair their progress or negate the value they have created.

Technology: In the span of approximately 9 months, the RTCE team transformed the ICE concept into a working reality. The team can now design low to medium NRE (non-recurring engineering) products in approx 4 to 12 hours compared to 2 to 4 weeks using their previous approach. Nineteen subsystem clients (ICE functional analysis tools) were written and technically validated. Over 7200 universal design variables were created, assigned and made accessible to every team member. A robust data management system was created and implemented. Automatic documentation tools – an idea initiated by team members as a process improvement – were added to each client.

In the next year, the team has several tasks that need to be accomplished in order to address some of the technical issues highlighted in the previous section. First, a sub-team must meet with representatives from the operations division in order to integrate their expertise into the real-time concurrent design sessions. New clients must be created as appropriate in order to provide the RTCE team with more accurate cost, lead-time and schedule information. Other ICE teams at JPL, Caltech and MIT employ 3-D visualization techniques so that designers can use their intuition to better understand how their subsystems will come together to form a high-performance machine. The RTCE should first implement a very low-cost, high-level tool such as Drawcraft which links the designer’s excel spreadsheet to SolidWorks®, a solid modeling tool (Liu, 2000). Once the team explores the benefits and difficulties of this new capability, they can then deploy a complex tool such as Pro-E®. The RTCE team must find a way to integrate historical data for comparison purposes. Finally, they must implement a rigorous and objective group decision-making methodology, such as MIT’s MATE-CON process, in order to explore the product architectures they create with respect to their customer’s stated values (Diller, 2002).

People: The original RTCE team kicked off the project with a high level of enthusiasm and energy. They were excited about a new way of doing business and knew that their leadership had committed significant resources to the success of the project (i.e. the entire overhead budget for the next year).

As discovered in the previous section, however, human issues slowed the team's progress and created conflicting messages. The RTCE project should be staffed with full-time dedicated personnel (Browning, 1996) and (Klein and Susman, 1995). This standing team will avoid conflicts of time, energy or loyalty and promote process improvement at an accelerated pace (Pomponi, 1998) (however, the modular structure of the RTCE process allows for subject-matter experts to be added as necessary, and for on-the-job training of new team members). It should consist of people from all functional and business departments – especially from marketing and operations. Team members should be chosen on the basis of their energy, cooperative spirit, innovativeness and system-level perspective as well as technical competence. There should be a healthy mix of "knowers" and "learners." The experienced seniors can help guide the team towards designs that will be less expensive to manufacture and that avoid failures that have taken place in the past, while the younger team members can help provide the real time, analytical horse-power the team will need to carry out its mission.

These team members should come together to establish common values and work norms. The leadership should effectively communicate their expectations to the team, and should explicitly evaluate and reward individuals and the team when expectations are met. The team should also create a forum for the training of new team members as well as an opportunity for others in the company to visit and learn about their process. Ergonomically, the team leaders should ensure that the team's homeroom is clean and quiet, that the temperature is comfortable and that all team members' human needs are tended to so that people can perform at their maximum potential.

Process: There are a number of key process achievements that the RTCE team was responsible for. They successfully integrated RTCE into the company's new proposal process. At this time, all new business opportunities utilize this innovative new technique. The team developed session scripting which enables people to understand the current focus of the design session, to facilitate information sharing and to keep the session flowing smoothly. The use of the "around-the-room" method allows each team member to share their input and have visibility to underlying assumptions and problem areas.

To complete the TPP analysis, the RTCE team should continue to focus on process improvement. They must create a feedback mechanism so that team members can voice opinions and implement their own process improvement ideas rather than leaving that burden exclusively to the team leadership. Metrics and goals should be posted and evaluated daily with a focus on continuous improvement. The team must avoid sub-optimization by encouraging system-level solutions even if one or two subsystems are less efficient than they would otherwise be. During the design sessions, two leaders are required to focus on different aspects of the process so that each team member can be free from administrative burdens. Having one leader who focuses on the technical aspects of the system and another that deals only with the smooth flow of the process will enable the team to operate at their maximum efficiency and have time to think innovatively.

The author also provided a roadmap for the integration of RTCE processes and concepts into the other phases of product design, manufacturing and test (Refer to Section B of Chapter 6). In the first phase of this effort, the RTCE team would enhance their current capabilities as described in the previous paragraphs. In Figure 4-G-2, the round circles that surround the ICE homeroom graphic indicate these additional team resources. Each circle could represent subsystem experts, additional team members, databases, or even small teams of suppliers or others who are available to assist the RTCE team during a design session.

Next, the team would build a "negotiation tool" that would help them rapidly provide detailed technical and financial updates to the negotiation team that is typically sent to finalize and sign a contract with each new customer. During the course of these negotiations (which typically occur in the offices of the customer), the negotiation team is often asked to sign up for increased performance or lower costs than initially offered in their written proposal. Using this new "ICE-on-a-laptop" capability, the team would be able to accurately evaluate the customer's requests and be able to show the customer the impacts or benefits of particular options. The tool they would carry with them to the negotiation session would be a high-level extraction of the full RTCE parametric model. It would have certain "design knobs" that could be tuned, but would also have a series of pre-determined 'limits' that would notify the negotiation team if they need to convene a full RTCE design session back home in order to update the proposal.

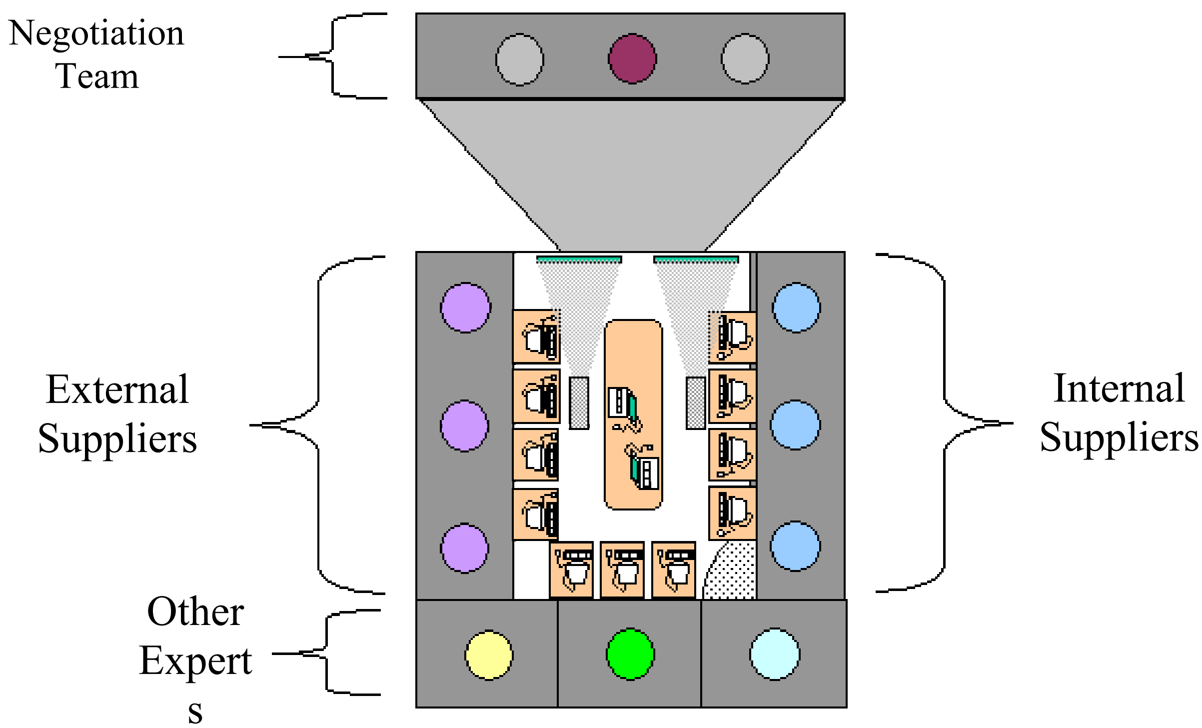


Figure 4-G-2: The off-site Negotiation Team is supported by the primary design team at home who are in turn supported by additional stakeholders and experts.

In the next phase of expansion, the RTCE process and models would become the backbone of all detailed design work that occurs after the company has won a new project. In the current system, the output of the RTCE team is mostly discarded because it is not in the format that can be used by the detailed designers, nor do they trust the analysis that was performed by people they do not know. In the proposed concept, the original RTCE team would gradually hand off ownership of the models and processes as a program comes to life. As more detailed work begins, teams of specialists can be added to support the main RTCE team. So, instead of having one subsystem model, an entire RTCE team could be plugged in to the system. The overall system model would be 'synchronized' on a daily or weekly basis by the main team in order to monitor the progress of the design work. These meetings would highlight new changes or issues that have arisen – designers would still be working with parametric models so they would be able to detect the impact that changes would have on their subsystems, and the project managers would be able to keep the team on schedule and on-budget by pacing the tasks that are to be completed by each update session.

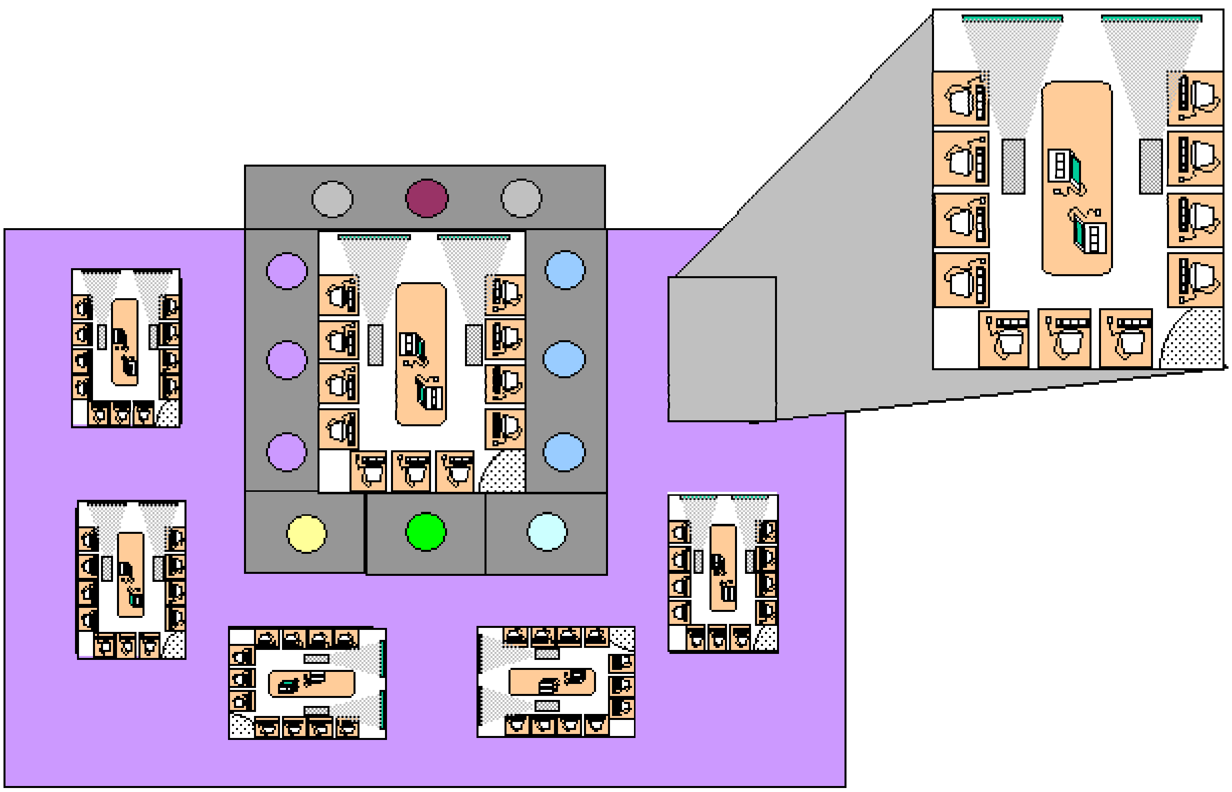


Figure 4-G-3: Other ICE teams are formed to support the primary design team. Their models are linked parametrically to the master product design.

Once the product design is complete and the team is ready to begin fabrication, the RTCE facility and models become valuable tools for monitoring the progress of hardware integration and performance with respect to the predicted values. If particular subsystems do not perform as specified, the models can help the team quickly assess the potential impact of the discrepancy and determine an accurate disposition. The system would also help the team perform and document complex system tests. Optimally, the manufacturing facility would be directly adjacent to the team homeroom so that the entire team can coordinate their activities and again see the impacts of their decisions in real time.

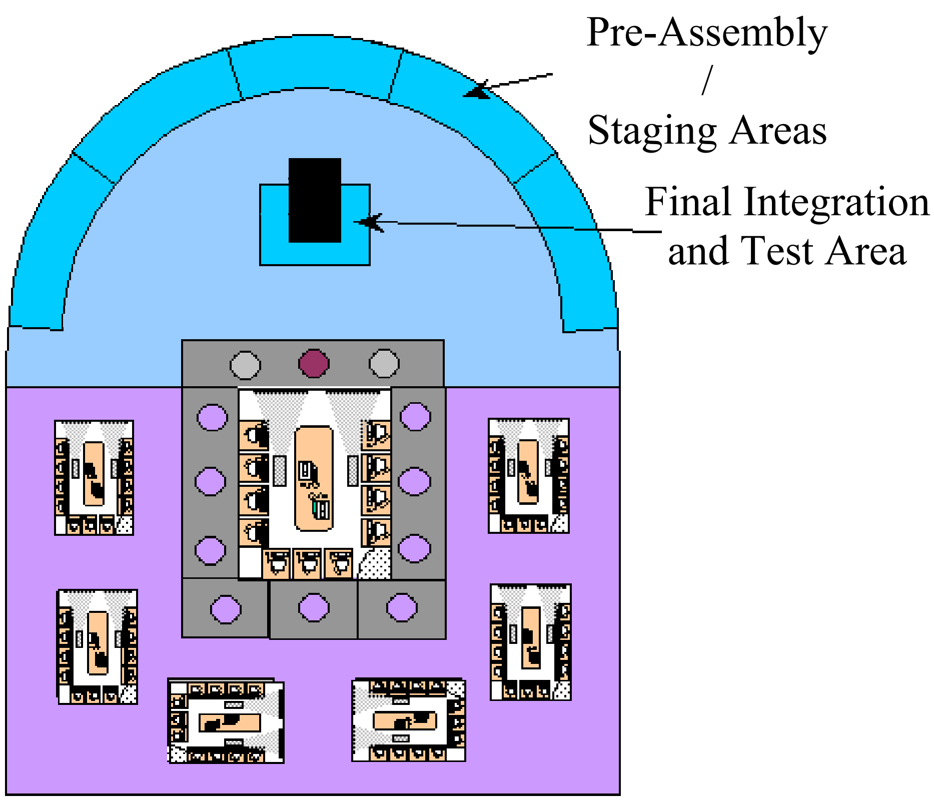


Figure 4-G-4: Collocation of Design and Fabrication Facilities for each new ICEnterprise will increase visibility and communication and keep the team focused on the smooth flow of operations in order to ensure on-time delivery.

Section 4-H: Summary of Organizational Implications and Recommendations

Summary of Organizational Implications:

- The nature of the company's organizational structure created barriers between the RTCE team, and the critical people and information they needed.

- Managers of other divisions within the company did not see the potential positive impact that RTCE could have on the company as a whole. This lack of buy-in manifested itself in the form of minimal support that detracted from the potential gains the team could make.

- The company's senior management team did not adequately understand the vision for the RTCE project. This was partly due to their focus on short-term profitability and partly because the RTCE leadership was unable to articulate a cohesive message to the proper audience.

- RTCE participants were thrust into entirely new types of jobs, and their training, motivation and incentives were not yet properly aligned with their new responsibilities.

- Managers in peer departments judged the project based on second-hand information and with respect to their own personal agendas.

- The RTCE leadership team faced difficult personnel and management issues yet lacked the authority or the mandate to make tough decisions and push team members to make changes outside of their comfort zones.

- Rather than enabling positive change, the company's accounting system prevented well-intentioned people from spending their time on work that would help make the company more profitable in the future.

Author's Conclusions on the RTCE team:

The real-time concurrent engineering team has created a jeweled "island of success" within their company (Murman, 2002). The team successfully brought about change during a complex and uncertain period of time. They applied innovative solutions to emerging technology, personnel and process challenges. The team worked passionately from their initial positions and reached out beyond the safe boundaries of their existing job descriptions. The organization around them responded defensively – the company had reached its current size and market dominance by forming a strong culture that resisted change. It gained efficiency through standardization, training and institutionalization – its customers paid for absolute predictability and reliability, not for unproven experiments, and the employees behaved accordingly.

The RTCE team leaders have successfully pushed beyond the boundaries of their home department. If the company is ever going to realize the tremendous technical and strategic value that the real-time concurrent engineering process can provide, the project must be supported and nurtured at the highest levels of the organization. The President must lay out a clear vision and follow through on a methodical expansion of the scope and impact of RTCE. The senior leadership should choose the most important attributes of this new business system – namely the continuity and universal accessibility of design information - and instill these as core values throughout the company. Next, the senior leadership should avoid the temptation to freeze and standardize the process as done with specific technical tools. Rather, they must foster an air of excitement and invention. They should clearly articulate the problems that the company is facing, and then describe in detail how a new approach that links all the key functions of the company in a manner never before possible, will provide a path toward sustainable success. There will be many new challenges along this path, but an approach that balances the technical, people and process issues will ultimately lead to long term, enterprise-wide value creation.

