Concurrent and Collaborative Engineering Implementation in an R&D Organization

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Abstract

The new economy is driving federal research laboratories to implement new ways for the management of their Research & Development (R&D) activities. This situation is very similar to that documented by many other organizations involved in R&D activities, where researchers are being asked to be relevant, to be more application-oriented, and to consider themselves key partners in the strategic management of the business. In addition, R&D is being asked to meet the same challenges as the rest of the organization, namely: 1) to reduce time to market; 2) reduce cost; 3) improve quality; 4) increase reliability; and 5) increase focus on customer needs.

Concurrent Engineering (CE), and Collaborative Engineering (or Collaborative Product Development - CPD) have emerged as new paradigms with significant impact in the development of new products and processes. With documented and substantiated success in the automotive and technology industries CE and, most recently, CPD are being touted as innovative management philosophies for many other business sectors including Research and Development.

This paper introduces two independent research initiatives conducted at the NASA Glenn Research Center (GRC) in Cleveland, Ohio investigating the application of CE and CPD in an R&D environment. Since little research has been conducted in the use of CE and CPD in sectors other than the high mass production manufacturing, the objective of these independent studies is to provide a systematic evaluation of the applicability of these paradigms (concurrent and collaborative) in a low/no production, service environment, in particular R&D.

Keywords

Project Management, Management of Technology, R&D Management, Concurrent Engineering, Collaborative Product Development

INTRODUCTION

Over the past thirty plus years the importance and need to manage projects across enterprise functions, such as new product development, created the need for project management [1]. The increased focus on more new products on a continuous basis, faster, and better, evolved from weak project management (coordinator) to strong project management (cross-cultural, mini-business manager) [2]. Still increased pressure on faster to market, with increasing complex products, in overlapping release times, evolved to simultaneous processes and then concurrent engineering (CE) [3]. With more distributed enterprising with national and international partners sharing in the new product development and electronically linked, CE has evolved to collaborative engineering or collaborative product development (CPD) [6].

These new paradigms (concurrency and collaboration) can have significant implications for the development of complex aerospace technologies and systems that are developed by Federal laboratories and their partners. This new way of developing technologies will produce changes in the ways aerospace systems are designed, tested, produced, operated, maintained, and disposed of.

CE is defined as [7] a "systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support ... intended to cause the developers, from the outset, to consider all elements of the lifecycle from conception through disposal, including quality, cost, schedule and user requirements." CPD is the application of team-collaboration practices to an organization's product development efforts. CPD builds upon the nature of cross-functional product development teams introduced by concurrent engineering. While CE has historically been concerned with the structuring of products, the flow of work, teams, and organizations, CPD is more concerned with creating the necessary environments for effective, free flowing and ad-hoc collaboration among peers [6]. As with CE, one of the primary motivators for continued collaboration that begins as early as possible is Pareto's rule, which states that 80 percent of the total cost for all resources is spent on 20 percent of the resources.

Research on the application of CE and CPD have been performed in high-production and/or manufacturing environments. Research into the applicability and benefits of CE and CPD into a low/no production, service, research and development, and/or government environment is limited. Most experts agree that aspects of these philosophies should be applicable to any kind of R&D setting; however there is limited research on the subject, as it applies to a

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government R&D environment. In addition, although there are some government CPD efforts, little or no research has been done on the application of these collaborative design environments to this type of organizations. As an "extension" of concurrent engineering, it can be expected that many of the benefits attained by CE practitioners would be achieved with a CPD environment. These benefits have been widely documented.

This paper introduces two independent research initiatives conducted at the NASA Glenn Research Center (GRC) investigating the application of CE and CPD in an R&D environment. Throughout the years GRC has been involved in the development of advanced aircraft technologies, space propulsion systems, communication satellites, the International Space Station and others. Because of the diverse nature of the R&D projects envelope, GRC provides an excellent model for this type of research.

The first study concentrates in the applicability of CE in the planning and implementation of experimental testing projects (ETP) at this R&D facility in support of research projects. The second study concentrates on the application of CPD in the management of technology and mission development (MTMD) activities of the NASA GRC project offices. Preliminary results and recommendations are based on a series of interviews conducted with senior and line managers at the NASA GRC, in preparation for subsequent surveys from which additional data is to be gathered and analyzed as part of the GRC's Continuous Improvement Process.

CONCURRENT ENGINEERING

As proposed earlier the benefits claimed by the use of CE seems to provide an answer to the challenges that R&D organizations are facing today. Although many experts have proposed that these benefits are transferable to any industry, research in the area of R&D is very limited.

To better understand the possible impact of CE we present a brief synopsis of the history of this philosophy. Traditionally all the activities of development have been accomplished following a sequential approach. In this approach, referred by many as over-the-fence engineering and officially documented by NASA in the 1960's, experts in each step perform their duties and pass the product to the expert of the following step. This allows specifications and design to be frozen by only engineering design decisions early in the process thus creating situations where upstream decisions will constrain downstream options [8]. As defined earlier CE has been an attempt to enhance the development process by creating a systematic interaction of all the functions and expert areas. Concurrency does not eliminate any of the stages required for product development but instead it focuses on a holistic consideration of all of these stages.

Systematic studies within the automobile and technical industries have substantiated that for a successful implementation of CE various critical factors or characteristics must be present [5]. These critical factors are:

- Strong Management Commitment
- Interdisciplinary and Multi-talented
- Comprehensive training to all team members
- Adequate resources and tools
- Early and continuous involvement of Customers and Suppliers

As substantiated by many researchers a successfully implemented CE program will give three main benefits. These benefits have been summarized as: reductions in total product cost, reductions in cycle time, and improvement in quality and reliability.

Concurrent Engineering in R&D

The purpose of our study was to evaluate the status of the use of the tools and techniques of CE on the success of experimental testing projects of an R&D organization. First the potential enhancers for CE in this environment will be identified and measured. The second objective of this study is to identify the barriers and/or constraints that this R&D environment presents to the successful implementation of the CE tools and techniques. Additionally, as a third objective the research focuses on measuring NASA GRC's state of readiness in utilizing the tools and techniques of CE. The findings of this study will be used to make recommendations and to propose a plan and strategy for strengthening the project management process at NASA.

1. Benefits and Impact of CE in R&D – This area of interest explores the effect on project success of each of the five key factors of CE. Hypotheses linking each of the key factors with the characteristics of project success are evaluated.

2. Enhancers and Barriers of CE in an R&D Environment – This area of interest explores the characteristics of successful projects in order to identify and analyze those factors that enhance and/or impede the successful implementation of CE in an R&D environment. Three features of project completion will be analyzed: project cycle time, project cost, and product quality and reliability.

3. GRC's State of Readiness for CE – This area of interest explores the presence of the five key factors of concurrent engineering within the management of NASA GRC experimental projects.

COLLABORATIVE PRODUCT DEVELOPMENT

One of the most comprehensive definitions of CPD describes it as *a systematic approach to control life cycle cost, product quality and time to market during product development by concurrently developing products and their related processes with response to customer expectations, where decision making ensures input and evaluation by all life-cycle disciplines, including suppliers, and information* *technology is applied to support information exchange where necessary [9].* From this definition, it is clear that CPD encompasses concurrency, attention to the life-cycle, suppliers, and information technology, all while maintaining a customer-focused environment.

Because of its key roles, GRC leads or participates in a wide variety of programs and projects, primarily as a provider of technology and other expertise. GRC works with NASA mission centers, which usually serve as Program leads for particular programs, as well as provide the funding needed by GRC for some of its R&D efforts. Because of the evolution of the Agency, and the technology available, many of the activities conducted for these programs and projects are collaborative in nature. However, as with any new paradigm, there is no "best of practice" model on how to best carry out these collaborative activities. Furthermore, the role of NASA's research centers as suppliers of technology and expertise for the Mission centers presents a unique opportunity to explore this new collaboration paradigm.

Collaboration is an evolutionary process, dependent on inputs, outputs, management influences, and environmental influences [10]. These factors are defined as:

- Collaboration inputs
- Management influences
- Environmental influences
- Collaboration outcomes

In addition to these factors, the role of GRC as a supplier of technology or expertise is another variable to be studied.

Early supplier involvement has been identified as one of the key success factors for collaborative new product development efforts in which the collaborative partner could be a supplier, customer, or competitor [11]. It has been shown that frequent inter-company communication, building trust, establishing partnership equity, ensuring that parties contribute as expected, and employing a product or collaboration champion increased the likelihood of success.

Summarizing, the key factors affecting the outcome of collaborations are:

- Choice of partner
- Clear ground rules for collaboration
- Limits of collaboration
- Allocation of resources
- Mutuality of contribution
- Personal chemistry
- Collaboration champions or mentors
- Tools and facilities

All these factors are being addressed during this study.

Collaborative Product Development in R&D

The information gathered from this research will support the development of a model for the application and expected benefits and challenges of CPD in this kind of organization. The research will also explore the importance of early involvement of the supplier of R&D expertise (GRC) in the development/design of new programs and missions.

This study on CPD provides the following contributions to the management of R&D:

1. Promotes the implementation of CPD by R&D organizations. The results of this research will include a model for the implementation of CPD in R&D organizations, which will ease the process of getting these R&D groups working with external organizations, as suppliers of technology and expertise. This will provide opportunities for improvements in the new product development process.
2. Explores and attempts to validate the benefits, costs, barriers, and enhancers of collaborative engineering that have been identified in the literature, but in a research and development setting. Furthermore, the enhancing role of information technology advances has not been studied in detail.
3. Explores the supply chain aspects of the R&D organization's relationship with its customers, or funding organizations. This is a new paradigm for most R&D groups, and this research will enhance the understanding in this area.
4. Provides the basis for follow-up research in specific areas within CPD.

RESEARCH METHODOLOGY

Both of the studies were conducted in two phases. The first phase was exploratory in nature and accomplished by conducting a series of semi-structured personal interviews. For Concurrent Engineering six GRC Division level management personnel, with a cross-functional view of the operation research experiments, were interviewed. For CPD the first phase was accomplished by conducting a series of semi-structured interviews with NASA GRC Division and Branch-level managers in both Project and Research & Technology groups. Although ordinarily unstructured interviews do no utilize interview protocols (schedule), protocols were used to provide overall guideline or framework for the conversation. The main objectives of these interviews were to provide data that helped in refining the research questions and guiding hypotheses and to provide information that was used to develop the structured questionnaires to be utilized during the second phase. The interview phase tried to encourage open discussion on the issues being studied. It is imperative to clarify that unstructured interviews are meant to be more flexible and open. Content analysis was used to analyze the information gathered during this phase.

The second phase consisted of the administration of structured questionnaires (surveys) to team members of various

R&D projects within NASA GRC. Well-designed structured questionnaires provide greater uniformity of measurement and thus greater reliability of the research.

For CE a questionnaire was administered to more than 200 GRC employees from the various functional groups involved in the performance of experimental testing. The respondents were asked to rate, based on their experience and using a Likert scale from 1 to 7, more than 90 statements related to CE. The data of this structured questionnaire on CE is being analyzed using simple regression and ANOVA methods.

For CPD a questionnaire was administered to an additional 200 GRC employees in the project management, and research and technology areas. In addition, a small (>20) number of questionnaires were sent to individuals outside of GRC in order to gauge the perception of GRC in a CPD mode by external parties. The data from these structured questionnaires on CPD is also being analyzed using simple regression and ANOVA techniques.

PRELIMINARY FINDINGS

The preliminary finding presented here are the results of the Content Analysis of the interview phase of both studies.

Concurrent Engineering Preliminary Findings

A total of six (6) division level managers with a holistic view of NASA research testing projects were interviewed for this phase of the study. A series of measurement questions were asked in order to focus the interview into the area of Concurrent Engineering but with enough flexibility to allow the interview to explore areas that may not have been considered by the conductor. The interview protocol was carefully designed to allow exploration in the three areas of interest of this study. As mentioned before the areas are the state of readiness of GRC for implementing CE, the enhancers and barriers of CE in an R&D environment, and the benefits and impacts of CE in R&D.

Responses were recorded and transcribed in order to allow a more effective content analysis. Clarification from the respondents on their responses was obtained as needed.

Regarding GRC state of readiness for Concurrent Engineering, the following conclusions could be obtained:

- CE understanding seems to be limited to the areas of manufacturing and design engineering (ME & DE)
- Groups other than ME and DE, namely, Test Engineering (TE), Research Technology (RT) and Test Technicians (TT) failed to understand the concept of CE.
- Limited presence of multifunctional teams
- Deficiency in CE related training

Presented with this misunderstanding the interview proceeded after CE theory was discussed and clarified with all respondents

Regarding the Benefits of CE in the R&D environment the following observations are presented:

- Reduction in total cost seems to be the primary benefit of CE. Citing Pareto Rule, and the Rule of 10 most respondent believed that the cost benefit comes during experiment testing and the operation of the research facilities.
- Reduction in life cycle is the second benefit of CE. Respondents agreed that CE will provide reduction in time cycle because better coordination amongst functional group will reduce the need for re-work.
- Time reduction is obtainable due to more efficient and less time consuming testing. Better designed experimental hardware will result in less research facility occupancy and testing time.

Regarding the Barriers and Challenges of CE in an R&D environment the following was identified:

- Organizational inertia in a government agency in particular an R&D laboratory. Traditionally R&D organizations have been compartmentalized. Although GRC has experienced progress in this area, there are still traces of this functional compartmentalization.
- R&D professional must have all the facts together before accepting changes. R&D professionals have been referred to as "trained skeptical".
- Prioritization of activities in R&D environment. Traditionally the culture of R&D does not impose target dates and clear deliverables. This cultural trend creates issue of prioritization of activities.

A final observation is the fact that in this environment meeting the technical requirements of the projects seem to be of most importance. In many cases cost and time to delivery is sacrificed as long as the expected product is delivered. This perceived weight of importance will be further studied during the survey phase.

Collaborative Engineering Preliminary Findings

Phase I of the study consisted of 7 semi-structured interviews with Division and Branch-level managers in GRC Project Offices and R&T groups. The interviews were patterned to cover the five factors identified previously, although, since they were semi-structured, there was room for the discussions to go into unplanned or unforeseen topics. The interviews were carried out in the summer and fall of 2002, and were recorded. They were carefully transcribed and a copy of the transcript was sent to each of the interview subjects so they could verify or clarify its content. Once the content was finalized, a content analysis was performed. The content analysis helped identify the salient issues that should be included in the Phase 2 questionnaire instrument. A brief summary of these key issues follows.

The main reasons for engaging in CPD were:

- Government policies encourage collaboration
- Need to leverage resources
- Multidisciplinary Nature of the work
- It's a win-win for the parties involved
- Enhances chances of being successful
- CPD enhances the political environment
- CPD is strategically/politically necessary

There were internal and external challenges:

- Existing rivalries between organizations
- Procedural or regulatory barriers
- Competition of government against industry
- Funding uncertainties
- Not enough buy-in from management
- Need for common goals and objectives
- Establishing trust
- Establishing the "One-NASA" frame of mind
- Being able to bring resources to the collaboration

All managers recognized the importance of both internal and external collaborations, and stated that their groups are engaged in both types. Practically every project they have involves personnel and resources from outside of their organizations. Typically, the scope, personnel, and funding level of external agreements are larger than the internal activities. Other key observations are:

- *One of the main differences between external and in*ternal collaborative activities is the type of agreement under which the collaboration is established.
- Collaboration internal to GRC is considered to be very effective.
- It is difficult to get external interest for collaboration unless there large programmatic budgets.

When discussing whether a collaborative *modus operandi* is more common now than in the past, most managers said their groups have been working that way for some time, but stated that it is indeed increasing. The tools and resources have changed, usually making it easier to collaborate. Some interviewed expressed concern that NASA Research Announcements (NRAs) may be a negative driving force for internal Agency-wide collaboration. Some of the drivers behind increasing CPD are: 1) Organizational issues; 2) resources limitation; 3) diverse customer base; 4) management directive for collaboration and; 5) complexity or programs and projects.

Finally, regarding customers, suppliers, competitor, and/or collaborators, there was unanimous agreement that in the NASA environment, most of our partners can be all four depending on the activity. This posed some interesting issues, such as trust and the development of long term working relationships.

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