USE OF THE CRITICAL CHAIN PROJECT MANAGEMENT TECHNIQUE AT NASA, LANGLEY RESEARCH CENTER

Andrew G. Hagemann; NASA, Langley Research Center; Hampton, Virginia

Why Use Critical Chain Project Management?

What would you say if you found a technique that enabled you to make a few fundamental managerial changes to create an environment where projects take between 35% and 50% less time to complete, and project teams have a 90% probability of completing their projects on time?

What would you say if those same managerial changes

- made it possible for some of those project teams to complete their projects early with no sacrifice in quality?
- made it possible to routinely establish a project schedule based upon the optimum allocation of resources for projects while guaranteeing that there were zero resource conflicts in that schedule?
- improved the quality of life for the members of your project teams to the point where their morale skyrocketed?
- significantly decreased the use of overtime?
- resulted in projects routinely being completed on time, on budget, and at the required level of quality?

Would you say, “That’s impossible!” That’s what I used to think until I discovered the Critical Chain Project Management (CCPM) technique.

Critical Chain Defined

A project’s critical chain is a combination of 1) the tasks that are on a project’s critical path and 2) the tasks that are assigned to the project’s critical resource. The critical chain is the longest chain of interdependencies, considering task and resource dependencies. Unlike the Project Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) which do not consider both task and resource dependencies, the CCPM technique insures that resource conflicts are eliminated before the task dates are calculated. Additionally, the CCPM technique accommodates schedule risk by inserting buffers into the PERT diagram, thus protecting the critical chain tasks from performance errors. These buffers do not ‘pad’ the schedule; instead, they act as shock absorbers to prevent the project end date from oscillating when critical chain tasks are not performed according to the schedule. The resolution of resource conflicts and the insertion of buffers are what help to mitigate schedule risk.

Based Upon Dr. Eliyahu M. Goldratt’s Theory of Constraints

Over the past two decades Dr. Eliyahu M. Goldratt, PhD, has published a series of books that have broken new managerial ground: The Goal, The Race, Theory of Constraints, The Haystack Syndrome, It’s Not Luck, and the Critical Chain. In these books Dr. Goldratt explains what he calls the Theory of Constraints (TOC). Although TOC was initially aimed at maximizing throughput in manufacturing plants, Dr. Goldratt has also successfully applied his theory to the discipline of project management [1].

To help him teach business leaders how to apply TOC to their organizations, Dr. Goldratt founded the Avraham Y. Goldratt Institute in New Haven, Connecticut [2]. Dr. Goldratt and his staff at the Goldratt Institute have developed computer applications that are TOC compliant. The product that the Goldratt Institute markets to the project management community is called Concerto®.

Other people have produced TOC-compliant software as well. A former manager and developer with the Goldratt Institute, and now co-founder of the firm ProChain Solutions, Inc. in Lake Ridge, Virginia [3], Robert C. Newbold has also developed a computer application for the CCPM community called ProChain Solutions®. Additionally, Mr. Newbold is the author of Project Management in the Fast Lane [4], a text that explains how to

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actually apply the principles of Dr. Goldratt’s theory.

Evolutionary, Not Revolutionary

Although the term Critical Chain Project Management is relatively new, it is an evolutionary project management technique and not a revolutionary one. A CCPM schedule continues to rely upon the establishment of a PERT network, the assignment of duration and resources – people, equipment or funds - to each task in that network, as well as the creation of project calendars and a resource calendar for each assigned resource. What is different is the way CCPM-compliant scheduling software uses the principles of TOC to identify and resolve resource contentions prior to calculating task dates, and the way it mitigates schedule.

Implementation at Langley Research Center

Before CCPM

Aeronautical research projects conducted at the Langley Research Center (LaRC) moved slowly and methodically through the wind tunnel testing cycle. Those who used our wind tunnel test facilities understood that our facilities were originally built as research facilities, and that it took time to prepare a test article for the test and to conduct that test. Further, the researchers understood that each change to a test article’s physical configuration is made by hand right in the test section. We did not have any desire to sacrifice the quality of our research for high throughput. We gave the researchers a great deal of latitude with the way tests were managed. As long as a researcher’s management style resulted in high-quality test results, our top managers did not see the need to change things.

Accordingly, researchers and test engineers had no need for PERT / CPM schedules. To achieve the required results within the estimated duration of the test, our test engineers and wind tunnel technicians were expected to work copious amounts of overtime without complaint for test after test after test. Unfortunately, this meant that wind tunnel entry and exit dates were often based upon conjecture leavened with a large dose of good fortune.

Because we did not use any disciplined project management technique our wind tunnel test cycle time was quite lengthy. Long cycle times caused researchers to have to wait so long between tests that when they did book manage to book a wind tunnel facility they stayed as long as possible to collect as much data as possible. To please our customers, we were then in the business of selling wind tunnel time.

How things have changed.

The reductions to the NASA aeronautical research and development budget have caused a reduction in the number of wind tunnel facility support personnel. Accordingly, the remaining support personnel have had to become much more productive. NASA wind tunnel facilities have also become much more customer-oriented as we seek to attract more paying customers to help the U.S. Government offset the high cost of operating its wind tunnel facilities. This means that NASA is striving to make its wind tunnel entry and exit dates as reliable as possible. NASA is also constantly striving to significantly increase each wind tunnel facility’s throughput while providing world class data quality.

LaRC began using the CCPM technique during Fiscal Year 1999 as a means of gaining a significant increase in productivity in our wind tunnel testing cycle. Because the regular and disciplined use of any project management technique was not part of the operation of our wind tunnel facilities before this time, LaRC management decided to use a pilot project to assess the validity of this planning technique. The six wind tunnel facilities that comprise the Research Facilities Branch were selected to become pilot facilities. This gave us a single point of control over the training and the implementation process.

LaRC is now in the business of selling wind tunnel test results rather than wind tunnel occupancy time. Accordingly, we are now operating these facilities more like business units, requiring that researchers define their test requirements sufficiently well for us to use statistical quality control methods to develop a test
regime that will produce world-class test data. We are also using the CCPM technique to create high fidelity schedules that model the process used to get ready for a test, conduct the test and tear down after a test. These schedules now accurately forecast wind tunnel entry and exit dates for each test.

The development and use of well crafted PERT/CPM models has now become the norm within RFB. The CCPM technique makes it possible for RFB personnel to make sure that their wind tunnel entry and exit dates are accurate and predictable. They are also developing state-of-the-art wind tunnel hardware to assist them in their efforts to produce ‘take it to the bank’ data quality.

**Large Cross-section of LaRC Managers Briefed First**

Before we were willing to commit ourselves to using CCPM at LaRC, we wanted to assess the validity of the concept. Knowing that we had to gain the support of the LaRC aeronautics community, we conducted a TOC briefing for a large cross-section of its people. This briefing was so well received that we promptly made arrangements to conduct a second briefing for another large group of LaRC aeronautics personnel who were unable to attend this first briefing. Because this second group of people also found great merit in adopting the principles of TOC, LaRC released a Request for Quote (RFQ) that solicited the implementation of a TOC-compliant planning and scheduling system within RFB.

**A High-Level Champion is Crucial To Success**

During the RFQ period we successfully obtained a champion from upper management to help us make the necessary changes. Our champion’s boss showed his commitment to the implementation by making this project the number one priority for our champion, agreeing to postpone a number of important initiatives to permit our champion to focus on this effort. Our champion then became an integral part of the implementation process, eventually becoming one of those who helped to conduct each of the ‘hands on’ training sessions performed in each of the six wind tunnel facilities. Those of us involved in this implementation agree that, without this champion’s high level of commitment and daily involvement, we would have failed to make the necessary changes, and CCPM would have been perceived by the wind tunnel personnel as another ‘management flavor of the month.’

**Everyone Is Trained Together**

To accomplish this implementation, each employee was trained at the same time. The training focused upon both the concepts behind the theory and how to apply these concepts in a particular wind tunnel facility. This was done to insure that each person had a common vocabulary and a common understanding of the new behaviors that each person was to exhibit on a routine basis.

Fortunately, this pilot program was a success and LaRC management decided to extend the use of this technique to the entire wind tunnel test cycle. During Fiscal Year 2000 the personnel assigned to the LaRC test article design and fabrication community were trained in the use of CCPM. The complete wind tunnel test cycle can now be fully integrated using CCPM schedules.

**Managerial Changes Were Required**

Within the first days of the implementation process we discovered that we had to revise our managerial practices if we were to successfully implement this new technique. Here is a summary of the changes that we made:

- LaRC now sells wind tunnel test results, not wind tunnel facility time
- Top management ranks each project in ordinal fashion (no ‘ties’ are permitted)
- Top management strives to maintain clear and stable priorities among projects
- Middle management strives to avoid creating a work environment where project team members must work on several projects at the same time
- Functional managers strive to assign personnel in accordance with the CCPM schedule developed by a project manger
• Functional managers reward personnel who finish work early

• Project managers plan their project before startup, using a CCPM compliant software package to ascertain the optimum mix and quantity of resources

• Team members no longer have to ‘pad’ task duration to accommodate working on multiple projects at the same time; i.e., duration is now estimated based upon the time needed to perform a task while working without interruption

• Project Managers now assess the health of their projects by monitoring buffer consumption, thus taking a global view rather than a local view

**Using Critical Chain Project Management**

Using the CCPM technique correctly requires familiarity with these two fundamental practices:

Bad multitasking

Task padding

Why are these two practices so important? Briefly, because multitasking results in lost productivity and the cumulative effect of padding tasks is a delay to the project's completion date. Remember the claims I made at the beginning of this paper? The reduction in project times comes from eliminating (or drastically reducing) multitasking. The high probability of completing a project on time comes from eliminating (or drastically reducing) the padding workers who operate in multitasking environments add to their tasks to protect their reputations.

**Effects of Multitasking**

People are multitasking when they are working on two or more tasks at the same time. This results in a lack of focus that causes productivity to diminish. Each time you stop working on a task before you’ve completed it and begin working on a new task, you have to mentally shelve your progress on the task you’re temporarily leaving. When you resume working on an uncompleted task you must mentally ‘pick up the threads’ from where you left off. This results in a loss of productivity.

![Figure 1 Productivity Is Lost Due To The Effects Of Multitasking.](image)

Ignoring the CCPM principle of clear and stable priorities a supervisor assigns a single resource three tasks to accomplish at the same time. The supervisor should have assigned the tasks in sequence, ordered by priority. If that had happened the total time spent on each task would have been three days. Since this didn’t happen, the resource juggles all three tasks, working a little bit on each one. Assuming that the resource didn’t need any time between each task to begin working effectively, each of the tasks could have been completed in six days. This isn’t often true in real life. What is far more likely to happen is that the resource must spend time between each task to sort things out before getting started. This results in a total time of seven days to accomplish each task. The lost productivity is significant. Multiply this by the number of tasks being worked and the negative impact on a project’s completion date due to lost productivity can be significant.

Starting a large number of tasks at the same time in the belief that doing so will result in the completion of an equal number of those tasks on

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1 Robert C. Newbold, *Project Management in the Fast Lane*, pp 27 - 28
time is a common tactic. Unfortunately, what results is a large number of tasks that are in progress but very few being completed. Because so many tasks are being worked simultaneously, the likelihood of on-time completion is poor. This multitasking between tasks results in delays to each task².

'Bad multitasking' occurs when a project-critical resource works on two or more project-critical tasks at the same time. Because project-critical tasks are by definition those that control the completion date of the project, any lost productivity here will have a direct and detrimental effect on the project’s completion date.

Please don’t think that since there is ‘bad’ multitasking there must be ‘good’ multitasking. Since productivity is lost whenever multitasking is employed, multitasking is to be avoided as a matter of course. However, some multitasking can be tolerated on non-critical chain tasks since these tasks do not control the project’s completion date. Too much multitasking on non-critical chain tasks can soon cause these tasks to negatively affect the project’s completion date, so careful judgement is called for.

By creating a work environment that eliminates (or significantly reduces) multitasking, a project manager is taking direct action to reclaim lost productivity. The need for multitasking is eliminated when management establishes clear and stable priorities. This one managerial change is what enables project teams to recover much of their lost productivity. This, then, is the basis of the claim that the CCPM technique can reduce project cycle times between 35% and 50%.

**Effects of Padding Tasks**

People who work in a multitasking environment will often protect themselves from being late on the completion of their tasks by padding their tasks’ duration³. Unfortunately, this ‘benefit’ occurs at the expense of the project’s completion date because the effect of task padding is cumulative, and the project end date is delayed⁴. Project managers have no other recourse than to convince their team members to reduce their tasks’ duration until the project completion date complies with top management’s desired completion date. In many cases this results in a critical path with zero Total Slack since each critical path task’s early dates equal its late dates. Project managers who find themselves in this situation have to cling to the forlorn hope that everything will run perfectly for the entire life of the project if their project is to complete on time.

Before the advent of the CCPM technique, project teams applied the Critical Path Method to a PERT model to establish their project’s critical path. Unfortunately, PERT / CPM does not accommodate schedule risk or create a schedule that resolves resource conflicts. PERT / CPM users soon discover that there is no way to maintain the project’s end date without ‘robbing Peter to pay Paul’ when ‘upstream’ tasks take longer to complete than planned. Assuming they are willing, the project team members cannot really know which of their tasks can safely have their duration reduced to provide schedule relief to the project. Because PERT and CPM do not address the negative effects of multitasking, the need to multitask is still present and the team members rely upon the padding they put in each task duration to protect their reputations. Reductions made to the duration of ‘downstream’ tasks do nothing to protect the project from the risk of these future tasks from missing their schedule dates. Additionally, there is a limit to how often the project can reduce duration because Peter eventually goes bankrupt.

Rather than ask team members to give up duration, a project manager may insert a sacrificial task toward the end of the critical path, essentially relying upon a single Peter. Unfortunately, this also serves to extend the project’s end date, and, as before, it also does nothing at all to mitigate schedule risk. Because all of this padding is placed at the task level and not at the project level where it can do the most good, there is no risk mitigation.

The CCPM technique provides a means of mitigating schedule risk. The CCPM technique inserts a kind of ‘shock absorber’ into the PERT model where it benefits the project the most. This is done by adding buffer tasks that protect the

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² Newbold, p 30
³ Eliyahu M. Goldratt, *Critical Chain*, Chapter 13
⁴ Goldratt, Chapter 13
critical chain tasks from performance errors. Coupled with a non-multitasking work environment, project team members can now provide task duration estimates that are as much as 50% less than before. Some of this padding that has been released due to increased productivity can be applied to buffers, making it possible to mitigate risk. This, then, is basis for the claim that the CCPM technique can provide a 90% probability of completing projects on time or early.

**How CCPM Works**

To begin the process of creating a fully buffered CCPM schedule we must construct a valid PERT model that fully documents the project’s plan of action. Each task is given a description a duration, the resources needed to accomplish each task are assigned, and the task’s dependencies to other tasks are established. The PERT / CPM diagram illustrated in Figure 2 is the basis for the subsequent illustrations used in this section.

![Figure 2 The Critical Path Is Established; Resource Conflicts Are Present At This Stage.](image)

Although we do not pad task duration when constructing a CCPM schedule, for illustrative purposes we will start with a PERT / CPM diagram that has padded tasks. This is done to make it more obvious how this padding inflates a project’s overall duration, and to show in dramatic fashion where the CCPM buffers obtain their values.

![Figure 3 CCPM Step 1: Push All Tasks As Late As Possible.](image)

The CCPM technique will resolve resource contentions, unlike the PERT / CPM process which cannot do so. The first step (Figure 3) is to push each task as late as possible. Unlike PERT / CPM resource leveling algorithms which move the project’s end date when a resource constrained schedule is calculated, the CCPM technique does not move a project’s end date. Although each task has been delayed as late as possible, there are still resource contentions at this point. This will be resolved in the next step.

![Figure 4 CCPM Step 2: Resource Contentions Are Resolved By Pulling Some Tasks Early.](image)

In the second step (Figure 4), the CCPM process checks each task assigned to a given resource for schedule conflicts. If a conflict is found, the tasks assigned to this resource are moved early to resolve resource contention. The project’s end date is not affected.

At this point an experienced PERT / CPM user may worry that so many of the tasks are scheduled according to occur as late as possible. Without a means to accommodate schedule risk, this would be

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5 Goldratt, Chapter 16
a grave problem, indeed. But, since the CCPM technique easily handles schedule risk by inserting buffers that act as shock absorbers for the project, (see Figure 7) this is not a problem.

Please remember that unlike the PERT and CPM techniques the CCPM technique is built upon a managerial philosophy that must be observed. Those who are successfully using the CCPM technique have institutionalized several key managerial changes based upon this philosophy. There is more to this technique than learning to navigate a new piece of software.

Figure 5 CCPM Step 3: Identify the Critical Chain.

Figure 5 illustrates the third CCPM step where the critical chain is identified. Remember that the critical chain is the longest path through the PERT logic, considering both critical resource and critical tasks. It is the identification of the critical resource that makes the CCPM technique so much more powerful that PERT / CPM. CCPM schedules resolve resource contention, making it easier for project team members to know exactly what they should be working on and when they should be doing so. This permits team members to focus on their tasks, chasing away much of the managerial clutter that so often caused them delays before the use of the CCPM technique was adopted. In the CCPM environment it is good to have a 'one track mind.'

Figure 6 Task Padding Removed For Illustrative Purposes To Show Where The Time That Will Be Allocated To Buffers Is Found.

In Figure 6 the task padding is removed to reveal the lost productivity that is caused by working in a multitasking environment. This is not one of the CCPM steps, but it is shown here for dramatic effect. Task owners are asked to provide expected average times and not padded average times since they no longer must multitask.

Assuming a normal distribution, these can be thought of as 50/50 times. Recognizing that half of the time the estimate will be wrong when using 50/50 times, the CCPM inserts buffers in the next step to accommodate this variability.

Notice how much time was freed up once all this padding is removed. Some of this freed-up time is used by the CCPM technique to create buffers. The remainder of the freed-up time is an increase in productivity for the company. Perhaps another profitable project can be placed on the company's books as a result of this increased capacity.

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* Newbold, p 82. p102
Figure 7 CCPM Step 4: Inserting The Feeder Buffers (FB) And The Project Buffer (PB). Until They Are Consumed, These Buffers Act As Shock Absorbers For The Project, Protecting The Project’s End Date From Changing After Each Schedule Update.

The final CCPM step (Figure 7) inserts the buffers into the PERT model. Notice that there are several Feeding Buffers (FB) and only one Project Buffer (PB). A Feeding Buffer protects a critical chain task from non-critical chain activities that feed it. The Project Buffer protects the entire critical chain, and is shared by each person working on a critical chain task.

By monitoring the Feeding Buffers associated with their tasks, team members who are working on non-critical chain tasks can ascertain for themselves just how much multitasking can be tolerated without causing a delay to the project. Obviously, multitasking should be discouraged, but there may be valid reasons for a non-critical chain resource briefly assisting someone assigned to another project.

The Project Buffer serves to accommodate performance errors all along the critical chain, thus protecting the project’s end date until the Project Buffer is consumed. The Project Buffer must not be consumed because of multitasking, however, since this consumption would be the direct result of a critical resource working on tasks that have nothing to do with the project. The Project Buffer is in place to accommodate errors caused by under estimating the duration of a critical chain task.

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7 Eliyahu M. Goldratt, Critical Chain, p 158

Why We Know It Works

Within one segment of LaRC’s aeronautical research community, all of the organizational units that comprise a wind tunnel test cycle can now use the CCPM technique. This segment can create schedules that both accommodate schedule risk and maximize the utilization of its human and physical resources. This means that a CCPM schedule can be used from the moment a requirement for a wind test is identified until the reduced wind tunnel data is delivered to the customer.

Although such a schedule crosses department lines, they can still be fully integrated. This integration permits a change in a wind tunnel’s availability to be known to all of the contributing entities. No longer are developers of specialized test hardware working frantically to meet an old deadline that changed weeks ago but no one told them of the new deadline. Test hardware can now be reserved with real dates rather than ‘wished for’ dates. Through this integration the effect of a changed due date can be rapidly known.

Within the wind tunnel test community, our users include Aeronautical Researchers, Model Engineers, Model Designers, Model Fabricators, Wind Tunnel Test Engineers, Wind Tunnel Technicians, and Wind Tunnel Facility Managers. Before the use of CCPM schedules these people had great difficulty finding time to take their vacations. Attending training classes, colloquiums, or seminars was even more difficult. Needless to say, morale suffered.

Now it’s a different story. Wind Tunnel Facility Managers are finding that it is possible to have as much as 50% of their workforce absent from the wind tunnel (on vacation or in training) and still maintain the same level of throughput that they were able to obtain when they had twice as many people on their staff. These Facility Managers are also reporting that they no longer need to have everyone work overtime during tunnel preparation to insure that the team meets a test’s scheduled start date. They are now able to identify weeks in advance the need for a key person to work overtime. This now permits the affected person ample time to arrange things with his or her family. Overtime is still being worked, but now facility managers use a targeted approach rather than a ‘shotgun’ approach. Obviously, this has helped to
improve everyone’s morale as well as save the Center money.

Morale has also been given a boost in the wind tunnel facilities because the CCPM schedules are built with input from everyone assigned to support a wind tunnel test. This has greatly increased communication among the team members, giving the wind tunnel technicians a significant role in the development of the PERT model. Each person now knows precisely how his or her tasks contribute to the success of the project. They now have a global view rather than a local, task-oriented view. Facility managers report that this has caused personnel to exhibit a surprising level of ownership in the plan.

Within the LaRC model design and fabrication community, the aeronautical researchers are finding that their projects are now going much more smoothly. As with the wind tunnel test teams, the model design and fabrication teams are reporting increased communication within the team and significantly improved levels of team member ownership in the plan. Due dates are being met reliably for the first time in ages.

Before the first drawings are begun, these model design and fabrication teams are quickly developing an optimized resource mix based upon a series of ‘what-if’ CCPM schedules. Within a couple of hours a team can easily make several changes to the resource assignments as they seek to identify an optimized schedule. Once the best allocation of resources has been established, the teams present their resource needs to top management for approval. This approval is considerably easier to obtain than prior to developing fully buffered CCPM schedules.

A LaRC Success Story

One of the first wind tunnel facilities to achieve success with the CCPM technique was the 8-foot High Temperature Tunnel (8-ft HTT). Think of this test facility as a liquid-fuel rocket engine lying on its side, and the test article is mounted where the apex of the flame occurs. Researchers use this tunnel to simulate the effects of a space vehicle’s reentry into the earth’s atmosphere.

When the 8-ft HTT Facility Manager and the Tunnel Technicians first began to use the technique they were immediately impressed by the amount of communication that was required to construct a valid PERT model. Technicians and engineers worked side by side to establish and validate the PERT logic, especially along the critical chain. This was a first, for usually the research engineers told the technicians what they were to do just before it was time to do it. After a few run-ins with each researcher who had his or her particular way of doing things, the technicians quickly learned not to offer ways to improve or standardize the process. Using the CCPM technique the entire team had to work together to create and document a plan of action before the project began. A strong sense of ownership in the plan soon developed among the entire team.

Once the CCPM schedule was accepted and the work began on the pre-test preparations, the technicians began to work according to the schedule. They soon discovered that they were able to stay focused upon the task at hand until it was completed. This ‘one track mind’ approach brought clarity of thought, helping to improve productivity and to reduce the probability of making an error. As you can imagine, making an error while working with highly volatile gases is not good. Stress levels began to drop almost immediately.

The team began to rally around the person who was working a critical chain task, helping that person to remain focused on the task at hand by fetching needed tools and parts for them. Since the task priorities had been sorted out before the project started each person knew how his or her tasks contributed to the overall project. Working to pass the work on to the next person as quickly as possible at the appropriate level of quality became the norm. One of the jokes going around the facility illustrates how quickly the tunnel technicians internalized this new work rule. “You’re working on a critical chain task, aren’t you? Don’t worry, I’ll take your coffee break for you.”

As part of creating the CCPM schedule an individual resource calendar was constructed for each person. These calendars accommodated each person’s vacation schedule and requests for training. The final CCPM schedule took these resource calendars into consideration, acknowledging that each person has a personal life.
Morale began to improve in earnest after the first member of the team was able to take vacation over the asked-for dates - despite the fact that the pre-test preparations were in full swing.

Although the need to work overtime declined, this was, initially, both a curse and a blessing. For those who’d grown accustomed to the extra money in their paychecks, the loss of overtime hurt a bit financially. However, the ability to regularly take weekends off and to take vacations as planned soon began to have a definite appeal, lessening some of the sting. The need to use overtime did not go away, however. It was occasionally used to restore Project Buffer, but its use was targeted at specific individuals who were working on a critical chain task. The Facility Manager no longer had to resort to a roundup of the usual suspects to find his crucial technician. This advanced notice was greatly appreciated on the home front as well.

The researchers soon began to see that the CCPM schedule drove itself, so to speak. Because the technicians had been part of the planning process from the beginning, each person was aware of what needed to be done and when it was appropriate to do it. The researcher and the Facility Manager no longer had to act as orchestra conductors, prompting people to start and stop. The first test planned using CCPM began and completed on time. Morale was definitely on the comeback trail at 8-ft HTT.

A significant gain in productivity was also realized. By 1999 budget cuts at the Center had reduced the 8-ft HTT personnel roster by almost half of its 1997 number. Through the use of CCPM this facility was able to complete as many tests during 1999 as it had during 1997. What makes this so much more interesting is the fact that the Facility Manager was routinely able to permit as much as half of his workforce to be away from the facility during any given week.

By eliminating bad multitasking and task padding, personnel assigned to the 8-ft HTT have increased their productivity by 50%. Through the use of buffers, they are completing their projects on time.

Conclusion
The implementation of the CCPM technique across LaRC’s wind tunnel test cycle has made such improvements to project schedule performance and team morale that other organizational units on the Center are now asking for training in the use of the CCPM technique. This, I believe, is the true measure of its success.

References