

AN INNOVATIVE DISTRIBUTED PROJECT CONTROL APPROACH: A CASE STUDY OF THE CASSINI MANAGEMENT INFORMATION SYSTEM (CMIS)

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ABSTRACT

The Cassini Project, a NASA-funded exploration mission to Saturn that is being managed by the California Institute of Technology's Jet Propulsion Laboratory for NASA, has developed a distributed project schedule control system for complex development programs. The system is called the Cassini Management Information System (CMIS). The system was built to make schedule control simple, user-friendly, and low-cost. CMIS is distributed across a local area network of PCs and Macintosh computers and consists of four major modules: schedule control, action item tracking, work package implementation plan, and budget tracking. This article focuses on the schedule control module of CMIS. CMIS was one of the innovations introduced in response to the decrees of the U.S. Congress, and subsequently NASA, to conduct space exploration on a fixed-price basis. This article summarizes CMIS development history as a schedule control tool, its key features, and its use by more than 130 engineers and managers.

Background

Originally, Congress approved funding for a joint program composed of a Comet Rendezvous/Asteroid Flyby (CRAF) mission and the Cassini mission. The program was authorized with the stipulation that it would be canceled if original cost estimates were exceeded. In response, Jet Propulsion Laboratory (JPL) chose to implement a classical earned-value system for controlling schedule and cost.

In 1990, after purchasing a full-featured commercial-off-the-shelf (COTS) project management system, the project hired 20 schedulers and planners to implement a fully integrated network schedule. The system was based on classic program evaluation and review technique (PERT) concepts (developed in 1958) and the Cost/Schedule Control System Criteria (C/SCSC) formalized by the U.S. Department of Defense in 1967. A large expenditure was made for training at all project levels.

By late 1991, CRAF/Cassini project managers observed some trends with the entire project control process:

1. The COTS project management system process countered JPL's effort to having decision making shifted to lower levels in the organization.
2. Considering the large expenditure for project control, no corresponding improvement was made with regard to communication between the different project elements.
3. The COTS project management system was not viewed as an easy-to-use tool.
4. The COTS project management system did not provide a straightforward method for addressing uncertainty.

A quick perusal of project management literature indicates the Cassini project's experience was not exceptional:

"CPM and PERT still tend to be tools for specialists not managers. Project management software is still considered an esoteric instrument by many. . . ."

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Unless project management can formulate unique tools, like it did in the '50s and '60s, and develop philosophy and culture tuned to the need of the changing corporate environment, it will soon disappear. Specifically, we need a new model for project management, we need a new mission, and we need simpler and smarter tools" (Tuman, 1993).

"Network-based techniques as planning tools do not consider the issue of uncertainty in identifying tasks and the relationship among tasks in the network" (Morad and Vorster, 1993).

"A network models only one set of schedule options at any given time" (Mathews, 1993).

"The current approach to planning and controlling complex projects has traditionally been to eliminate uncertainty and change from our projects, or at least treat them as if change will not occur" (Archibald and Lichtenburg, 1994).

"Older packages emphasize the critical path method, which can be very clumsy when scheduling people. Classic approaches tend to be expensive and rooted in legacy technologies" (Wood, 1995).

In short, the project found that the cleanliness of theory (PERT, C/SCSC) was no match for the clutter of reality.

A New Approach

In late 1991, the U.S. Government canceled the CRAF portion of the program. Because the cancellation resulted in developing one unique spacecraft instead of two virtually identical spacecraft, the number and complexity of the intra-project interfaces remained essentially unchanged. However, all areas of the Cassini project, including the planning and control area, were required to reduce costs.

In response, in early 1992 the Cassini project decided to focus on schedule control and develop firm annual and run-out budget allocations (including contingency) for each project element. While this approach did not provide integrated cost/schedule tracking, project management blunted the potential for cost overruns by:

Relying heavily on fixed-priced contracts with major suppliers

Implementing detailed monthly management reviews at the element (or subsystem) level

Collocating the project workforce into six closely located buildings

Empowering all technical managers to be fully accountable for the successful cost, schedule, and performance of their respective elements.

The last item was accomplished by converging the project's management organization and work breakdown structure (WBS) (Exhibit 1).

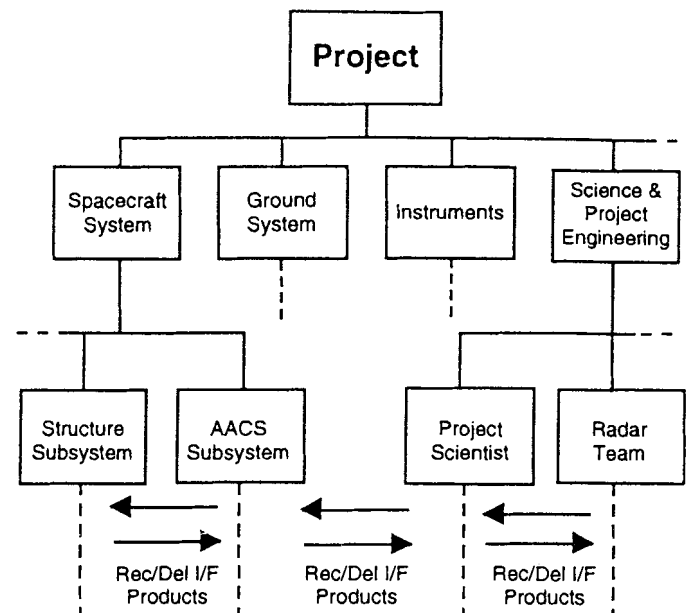


Exhibit 1. The product-oriented WBS with Rec/Del interface products shown.

The WBS depicts the project's organizational breakdown into its various elements. Integrating the project's organizational structure with its WBS resulted in one technical manager being assigned to each WBS box. One of the key CMIS conventions was to require each technical manager to identify his or her input and output products (receivable/deliverable interface products) with the other technical managers across the project, as shown. Products are designs, components, parts, assemblies, tests, etc.

CMIS Schedule Control Implementation Conventions

The CMIS schedule control system relies on five simple conventions:

1. All project products have to be someone's deliverable (Del) and another's receivable (Rec). While this concept is not new at JPL, its formalization as a rule for all products has been critical to successfully developing an internally consistent project plan. Because of this convention, all products became known as Rec/Dels.
2. Once a deliverer and receiver reach an agreement on the need for and delivery date of a product (in other words, Rec/Del), a contract is formed.
3. Each Rec/Del agreement (contract) is tracked and stored as a single record in a database.
4. Any person on the project is able to determine a Rec/Del's status at any given time from their local PC or MAC workstation.

5. Only the receiver (that is, customer) can decide whether a product delivery has been successfully completed. This solved the problem of the deliverer saying, "I delivered it," and the receiver saying, "But it doesn't work."

With the implementation of fixed-price work packages at the subsystem/element level, CMIS allows upper management to focus more resources on monitoring and controlling the interfaces between areas than on monitoring individual areas. Contrary to typical planning and control methods for large projects, CMIS's distributed nature (products being defined, input, and reported on directly by the project managers and engineers) avoids the need for a central staff of planners and gives managers direct control of their plans. PERT/CPM tools are still used by subsystem/element technical managers to manage their own areas of responsibility. Because the project does not roll up an integrated network schedule across the entire project, technical managers are free to choose an internal control system appropriate for their own effort.

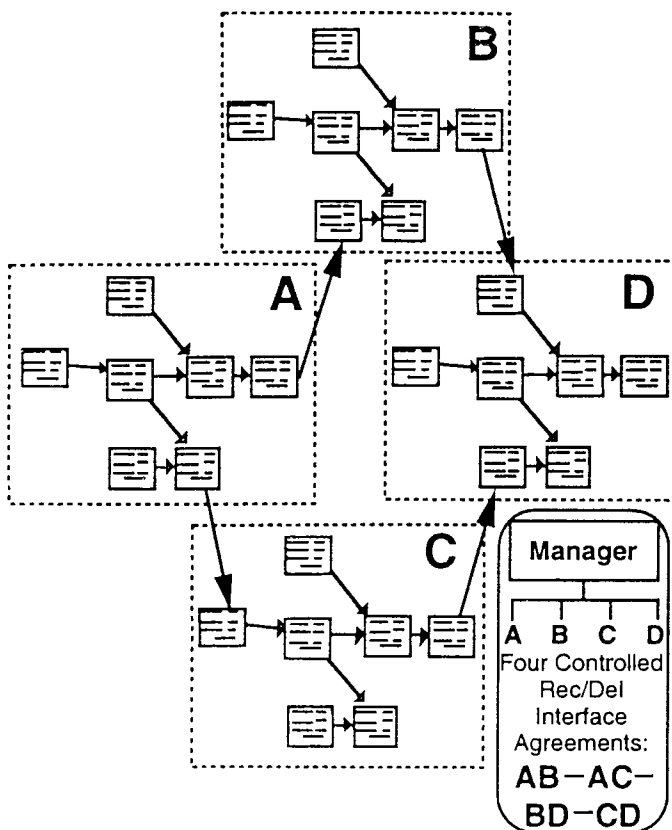


Exhibit 2. A simplified example of a distributed scheduling approach.

Exhibit 2 depicts a simplified example of CMIS schedule control. Subsystem/element technical managers A, B, C, and D have created their own network schedules of three events each. Manager A's schedule delivers a product to manager B and a product to manager C. Both managers

B and C deliver a product to manager D. The system manager over these four technical managers would then monitor the four controlled interfaces (Rec/Dels) between the four schedules. The subsystem/element technical managers are able to replan their work to meet unforeseen events within the constraints of their interface agreements.

By implementing the conventions and process described above, CMIS became a *centralized* control system that simultaneously facilitated *decentralized* decision making. The value of this approach became immediately apparent:

1. The CMIS schedule control module facilitated and increased communication. It also highlighted where communication between project elements was deficient. Product specification and delivery schedule disputes were easily identified, problems were quickly addressed, and schedule confusion vanished.
2. Schedule tracking and statusing became virtually effortless. The project implemented an automated statusing system that polled receivers on a weekly basis about whether they had received their agreed-to deliveries for that week. Receiver responses to the messages were automatically compiled and summarized in weekly metric reports to management. In addition, on-line statusing within CMIS was provided.
3. The single-database design allowed current project-level schedule reports to be generated at any time.
4. CMIS reduced centralized project control costs to less than 0.25% of the total project budget. The workforce of planners/schedulers dropped from 20 people to an operations staff of 3. This yielded a savings of greater than 60 work-years over the project's development phase.

The CMIS Schedule Control Module

The first CMIS module was a simplified schedule control tool. As Rec/Dels were entered into the system, CMIS reports (described below) quickly identified interface disparities and disputes across the project. Later, as such issues were reconciled, management used the CMIS project control system primarily as a schedule control tool for tracking the completion or re-scheduling of Rec/Dels.

Data Entry. To initialize the schedule control process, each technical manager submitted a list of the input products they needed (that is, receivables), who they expected to get the input products from (that is, deliverers), and when they needed to receive these input products to produce output products on time. They also listed the output products they were developing (deliverables), who they thought needed the product (receivers), and when they planned to deliver the output products. With the advent of

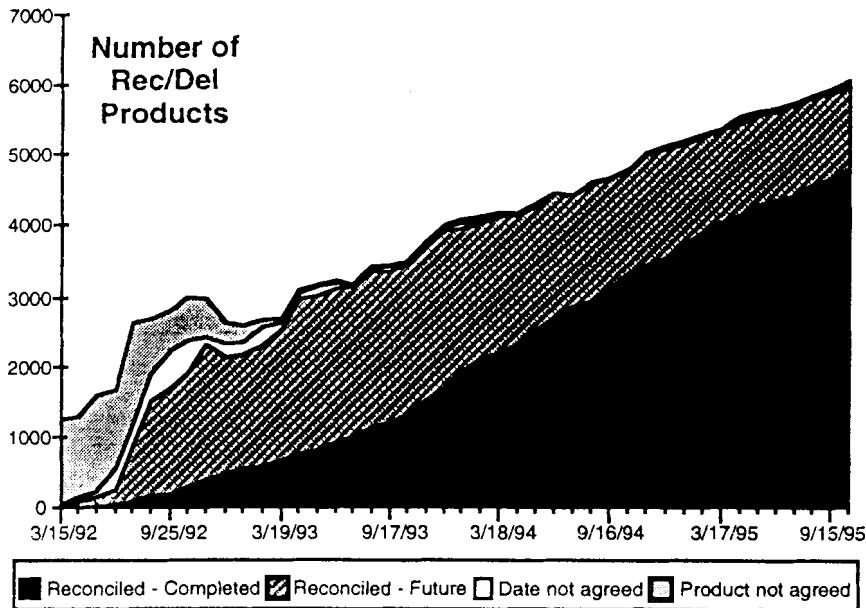


Exhibit 3. Reconciliation graph.

on-line data-entry capabilities, optional memo fields were added to allow more detailed Rec/Del specifications.

CMIS Schedule Control Module Planning Reports and Metrics. Before CMIS implementation, many seasoned managers expected that the simple level of formality (that is, requiring technical managers to input only the product's name, source, destination, and delivery date) would not be beneficial. This perception changed dramatically when only 3 of the initial 1,200 products submitted to the CMIS database had matching receiver and deliverer information. Moreover, technical managers quickly recognized that CMIS allowed them to formalize their *external* delivery commitments without limiting their ability to modify their internal schedules to best meet their delivery commitments.

The reconciliation process found holes in the plan where needed products were not being supplied or were being supplied but not needed. The process also uncovered many occurrences of product delivery dates that were much later than those needed by receivers.

CMIS provides metrics for tracking the level of reconciliation at the project, system, and subsystem levels. Rec/Del metrics are reviewed weekly by the project manager and his staff. Lack of a reconciled plan immediately draws management attention. Technical managers strive to avoid being placed on the "most wanted" list, which is the list of subsystems with the highest number of unreconciled Rec/Dels. A reconciliation graph was generated for both the overall project and the four major development offices: Spacecraft, Instruments, Science and Project Engineering, and Ground System. This chart provides management with a means of gauging progress toward achieving a fully reconciled plan.

Exhibit 3 shows the project's reconciliation progress from inception of the Rec/Del system to October 1995, with the completed Rec/Dels superimposed on the reconciliation chart. The chart is divided into four categories:

Product Not Agreed: Rec/Dels for which either the receiver or the deliverer disagree on a product's existence or description.

Date Not Agreed: Those Rec/Dels for which the receiver and the deliverer disagree on the delivery/required date.

Reconciled-Future: Those Rec/Dels for which the receiver and the deliverer agree on a product's description and the delivery dates but that have not been completed.

Reconciled-Completed: Those Rec/Dels for which the receiver and deliverer agree on a product's description and the delivery dates and that have been completed.

The CMIS on-line schedule control module provides technical managers with easy access for monitoring and updating their Rec/Del interface agreements. CMIS user read/write privileges are controlled to ensure that users can only change their respective portions of a Rec/Del agreement. In other words, receivers can change only the receiver part of the information, while deliverers can change only the deliverer part of the information. Once a Rec/Del is agreed to, it is treated as a contract between the two areas. If one party changes a Rec/Del, it is no longer considered to be in agreement, and the change must be reviewed and accepted by the other party.

CMIS Plan Performance and Maintenance. As reconciliation among Rec/Dels occurred, project management's focus shifted to the actual performance of the plan. Recognizing that useful performance metrics required timely statusing, several automated weekly electronic mail reports were developed. These messages provide users with Rec/Del change notices and remind users about deliverables due within 2 weeks.

As described above, receivers are automatically polled to find out whether or not they have received their planned receivables. (While users can elect to status their receivables electronically, most statusing is done during on-line sessions as managers regularly review and update their Rec/Del agreements.) This simple customer-driven (receiver-driven) system has proven extremely effective in identifying missed deliveries or delivery disputes. All receivers know that if they status a delivery as being not

received, management will know about it immediately. Missing status and missed delivery reports receive attention weekly at all system-level staff meetings. As one manager put it, "There's no hiding if you're late."

Some other examples of CMIS reports include:

Unreconciled Items: Rec/Dels that have not been fully reconciled.

Broken Agreements: Rec/Dels that have been fully reconciled in the past but are currently being renegotiated. (The close tracking of broken agreements by management has given early insight into potential problem areas.)

Missing Status: Rec/Dels that should have been delivered by the current date, but the receiver has failed to either confirm delivery or declare a missed delivery.

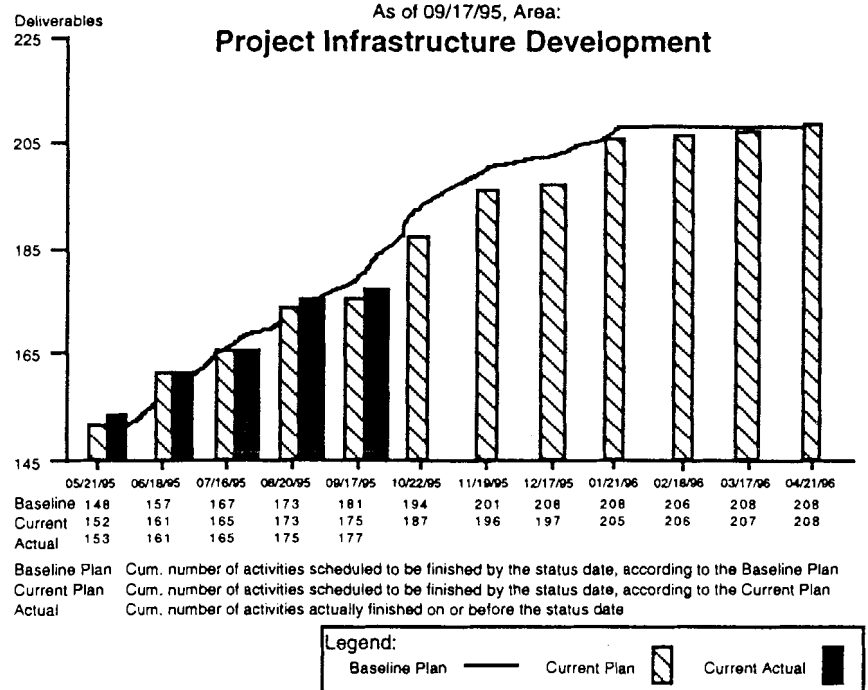
Missed Deliveries: Rec/Dels that should have been delivered by the current date but the receivers have designated them as missed because either nothing was received or the item that was delivered did not meet agreed-to specifications.

One of the metric charts that CMIS produces (Exhibit 4) compares the actual completion date of Rec/Del products to the baseline plan date and the current plan date of product deliveries over time. (The *baseline* plan is the original agreed-to delivery date for a Rec/Del. The *current* plan is the most recent agreed-to delivery date for a Rec/Del.) Planned-versus-actual metrics are generated for all project levels, which show past and current performance and allow management to accurately project required future performance consistent with existing plans. For example, steeply sloped curves typically point to unrealistic plans or critical parts being delivered to many different "receivers."

Early Indicators of CMIS Schedule Control Module Success

When compared to schedule control practices of past NASA spacecraft development programs conducted by JPL,

Twelve Fiscal Month Baseline vs Planned vs Actual



Twelve Fiscal Month Baseline vs Planned vs Actual

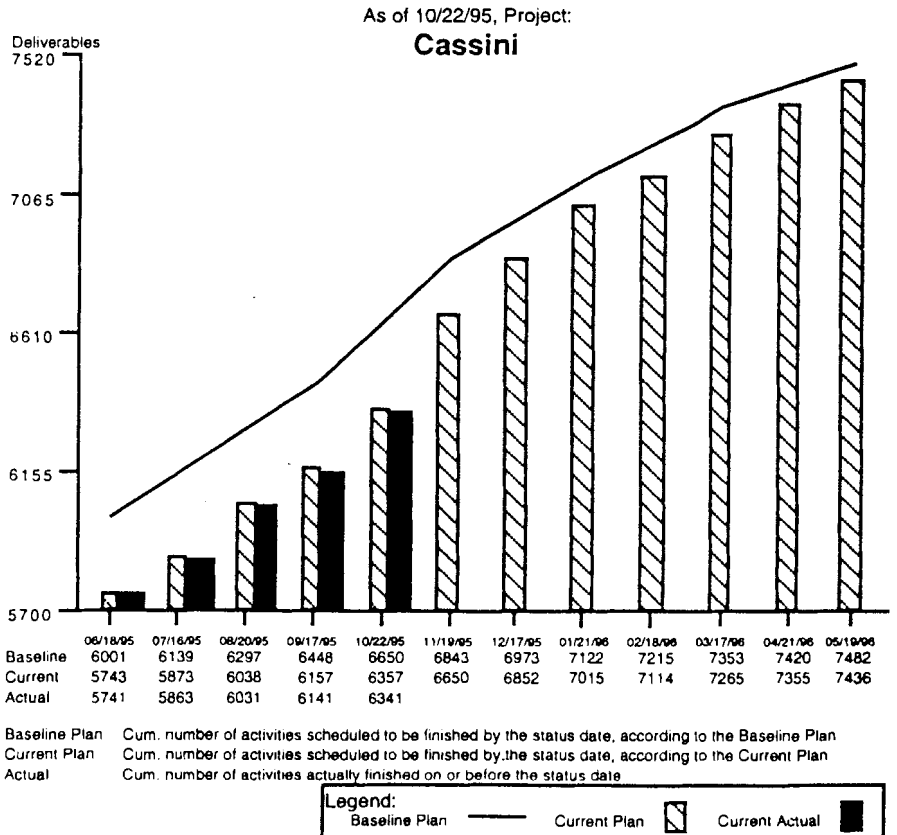


Exhibit 4. Baseline vs. plan vs. actual charts. (Top is for an area, bottom is for the whole project.)

CMIS has revolutionized schedule control. The system was easy to implement and immediately useful. Plan inconsistencies and missed or slipped deliveries are now immediately apparent, and their existence is indisputable. This information has facilitated the early definition of no-cost problem resolution plans. Moreover, since CMIS implementation, more than 5,000 additional product deliveries have been voluntarily added by receivers and deliverers to better define the interfaces between project elements.

The most surprising result of CMIS has been the overwhelming positive response to the CMIS project control system at all levels of management and staff. Typically, project control systems have the stigma of being for, of, and by top-level management. Although CMIS was developed as a management tool, it has been voluntarily accepted and adopted for detailed planning at the working level of the project. At the end of March 1995, the on-line system had more than 130 different users and was averaging more than 700 sessions per week.

CMIS usage is expected to increase as JPL develops and implements a plan for extending the system to the non-JPL elements of Cassini at NASA headquarters, NASA Lewis Research Center, and the U.S. Department of Energy and to the supporting efforts at universities and by contractors and foreign countries. Over the next year, CMIS usage will also be extended to non-Cassini project efforts within NASA at JPL and at other NASA centers.

Conclusions

The following general conclusions can be drawn based on the Cassini project's experience with CMIS:

For large research and development projects, effective cost and schedule control is possible without incurring the large costs associated with centralized project control systems.

An effective cost/schedule management information system for all levels of management can be built by focusing on satisfying the requirements of first-line managers and lead engineers. Such an approach removes the inherent noise in management reports created by planning and control staffs.

An effective way to deal with schedule uncertainty is to simplify the project control approach to focus on the areas where schedule uncertainty has the greatest impacts (that is, the interfaces between receivers and deliverers).

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