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An analysis of the situation and current trends
in the management of construction projects at
Los Alamos National Laboratory

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I. Introduction

The management of project development, design and construction at the Los Alamos National Laboratory (LANL) is complex and difficult. As a newcomer, it has been a challenge to gain even a partial understanding of the process and problems. While I think my reasoning is sound and based on facts which can be verified, it is better to consider hard statements as prefaced with "It appears to me that"

At LANL there is a move to switch from reliance on rules to an expanded reliance on market forces, as evidenced by the facilities recharge program. This sort of change is not a simple matter. Rules can be used to achieve greater control. They result in part from heightened DOE involvement, the greater influence of ES&H regulating functions, and the lengthy project justification and budget process. Market forces appear to offer greater efficiency by bringing competition into the project delivery process. Some balance between approaches must be found as it is unlikely that the rules associated with the funding processes and ES&H requirements are going to be reduced or that a completely free market is going to develop.

This paper moves beyond the market/rule debate to argue that new approaches to project management are required. Managers at all levels in the LANL face contending demands as they are caught between immediate concerns and long term consequences, keeping track of the big picture and looking after the details. Management techniques appropriate for simple certain projects will be of limited value on complex uncertain projects built on tight schedules - no matter how market and rules are balanced in the larger organization. Thus the degree of complexity, uncertainty, and duration, should shape the choice of project management approaches. Single dimension simple buzz word solutions will do little good and may cause harm.

This report reviews current situation and efforts underway to improve performance are reviewed. These efforts are shown to be useful but incomplete as significant improvement will both require altering and expanding how managers and the management system respond to contending demands.

II. Current Situation

Four components define the current situation; 1) Problems with project delivery, 2) A complex, lengthy and ever changing project development and delivery process, 3) A large backlog and continuing construction development

efforts are out of proportion to the amount of completed construction, and
4) Dissatisfied people.

1) Problems with project delivery

Projects frequently overrun the budget and schedule. In some cases these problems are reported to be associated with the poor definition of the project baseline, or the failure of project programming to make decisions which will remain stable over the life of the project. In other cases, the problems arise during the project due to unexpected events and/or new requirements.

2) A complex project development and delivery process

The project development process is a long chain of events. The requirements for completing some of these steps are clear but actual decision criteria are not clearly stated. While the major milestones in the sequence are followed, the process within activities is far less well defined. The interactions between various groups - particularly those with ES&H concerns - are not limited to one-time reviews.

Discussions with CPM suggest that the project development process from project initiation is not a clearly defined sequence of events but rather a reciprocal negotiation between various agencies and the client. The project development process establishes hard constraints before the project design is well enough developed to support accurate forecasting. In effect line item projects have the highest uncertainty and the lowest flexibility. Incremental annual release of project funds complicates the planning process.

3) An imbalance between project development, backlog and completed projects.

The FY93 construction program is about \$24 million while the backlog is about \$1.4 Billion. There are about 15 construction project managers involved in both project development activities which add to the backlog and managing projects under construction. Apparently, in the last year there was nearly the same amount of money spent on project development as there was on actual construction in FY92. The projections shown in table 4 in the Site Development Plan Annual Summary (LALP-92-17) suggest that the volume of work installed will increase to about \$60 million per year in the near future.

4) Dissatisfied people

Clients, senior management and staff, and people in the Engineering Division are dissatisfied with both the results and the effort required to complete projects. Clients question the competence and productivity of Engineering Division staff and management. Likewise people within ES&H functions express reservations about the extent to which their regulations are accepted. Within Engineering itself dissatisfaction arises from a multitude of perceptions including 1) the lack of incentives for contractors and CPMs to control cost (even though the contracts are fixed price), 2) a poorly functioning cost system, 3) the weak position of the CPM in regard line managers, 4) the lack of a sense of team identity and the large number of parties involved in each project, 5) the lack of goals and authority within the Engineering division, 6) the lack of feedback on performance, 7) the lack of computer technology, 8) the lack of training and high turnover of people, and 9) conflicting directives and requirements from DOE.

There is also significant dissatisfaction within ENG -1 due to the large number of project participants, heavy work loads, lack of authority, lack of information for cost control and the status of key project issues, a sense of little support from other groups such as ENG - 2, 3, 4, & 5. CPM are also troubled by the variety of demands imposed by different clients, different project funding rules, and evolving orders and regulations.

III. The problem as perceived at LANL.

There is a clear sense that DOE, LANL management itself and clients are dissatisfied with the overall project development and construction process. This dissatisfaction surfaces as complaints that the ENG-1 is not responsive to clients despite the acknowledged complex management situation, changing laboratory mission, multiple very independent clients, multiple sources and conflicting constraints within DOE, remote location, high security requirements, and extensive environmental and health and safety issues.

While the clients are unhappy, people particularly those in ENG-1 feel almost overwhelmed by both the magnitude of uncertainty faced at each point in the life of a project and the sense that people in ENG can do little to affect the situation because they lack authority, have a sense that the rules are constantly changing, and project constraints may be unrealistic or ill-informed.

IV. The way the problem is being managed.

Efforts are underway to restructure the Engineering Division, improve project delivery control technology, educate the clients about the project process, and to charge for facilities engineering services.

Within Engineering:

In order to educate clients and provide a common understanding of the development process, a "Facility Project Handbook" has been prepared which outlines the formal steps required to develop and complete Expense, GPP and Line Item Projects. Recommendations have been made for reorganization of project management within ENG-1 to group CPM by client based teams. The Handbook and reorganization clarifies the steps in a project and offers the promise of improved responsiveness through more effective application of resources within ENG-1 and through more coordinated efforts between the ENG-1 and other organizations. A "Continuous Improvement Team" has been established to further study the engineering Process, the customer's need and requirements and possible reorganizing solutions.

At the LANL level:

A system of charging clients for space utilization (recharge) and project management services is well on the way to implementation.

V. Discussion:

The approaches being pursued to solve the problem of client responsiveness include; 1) better educating clients about the project process, 2) altering the structure of ENG-1 to group CPM in teams by Client, 3) improving the skill level of CPM in the application of critical path scheduling to better plan and control the process, and 4) establishing a system to charge clients for Engineering services.

These solutions reflect the belief that the primary problems are related to or can be solved by ENG-1 achieving tighter control of downstream activities and through the use of market mechanism to force efficient practice. This belief rests on at least four questionable assumptions. Improving client satisfaction with Engineering will be limited by the extent to which these assumptions reflect reality.

The questionable assumptions include:

- A. Projects are relatively independent of one another and of existing facilities and emerging programs at LANL.
- B. Project development and management processes are simple, sequential, accurately described in the manual, and can be followed. Activities within each activity are well structured, and the rules clear and predictable.
- C. Uncertainty inherited by the manager at each point in the process is low.
- D. Parties within DOE, LANL, ES&H, & the contractors have common goals and agree on the relative priority of projects.

If these assumptions are false, the proposed solutions will be only partially successful. Reorganization within engineering, shifting engineering functions, charging for services, may each be useful. But they will have limited impact until the problem is redefined and difficult underlying questions are raised and answered. Further in some cases, the approaches currently favored may add to the difficulty.

The choice of project management approaches or theories to be applied depends on three variables;

- 1) Are key features of the project certain or uncertain? Is the technology well known and are the project objectives clear and stable? At LANL the answer must be uncertain, particularly given the shifting role of the lab and the evolving regulations and constraints.
- 2) Is the project simple or complex - that is to what extent does the project interact with other projects or activities? The answer is complex - due to 1) the internal technical complexity of the design and construction of the facility, 2) the interactions of the facility with other facilities and the environment, and 3) the limited availability of management resources.
- 3) What is the pace of the project - slow or quick? The answer at LANL is slow until they become quick. It takes a very long time for projects to mature to the final design and construction phases, but once in

construction the pressure for completion is high.

VI. The problem redefined.

Construction projects at LANL are often extremely complex, uncertain and quick. The current organization and related management techniques while well suited for simpler more certain projects are inadequate. (This problem is not unique to LANL. There is widespread difficulty in managing complex, uncertain projects under tight deadlines. Even the Project Management Institute is beginning to admit that critical path scheduling and downstream control are inadequate.)

Consider the demands on project management in four different situations. If the project is simple and certain - like scheduling trash collection, the solutions will be found in using information technology and planning specialists with scheduling techniques to coordinate and control activities. If a project is complex but certain - like conducting a symphony, great advantage will be found in the cooperation and teamwork associated with integrating the organization through process design and facilitation, and more clearly defining roles, responsibilities and the timing of efforts.

If a project is complex and uncertain, the focus shifts from control and coordination of down stream activities to the stability of upstream decisions - as in the planning required to take a family on an extended vacation in a developing country. Here uncertainty is reduced through the search for information and redundancy. Stable decisions are those which include flexibility to absorb the remaining uncertainty. For example, by leaving roughly a week at the end of the trip to relax on the beach near the departure airport.

But what if a project is uncertain, complex and quick? Here the organization must support and managers must be capable, as Alex Laufer says, to "Orchestrate Contending Demands." One person must be able to balance the details and the big picture; to keep one eye on the emerging regulatory environment and the immediate situation. There are few models for this kind of management. Attempts to manage these projects with only those techniques appropriate for less challenging jobs will meet little sustained success. In particular, dividing responsibility for short and long term considerations can cause great frustration as those managers tasked with execution and control of sub-tasks will find their work is constantly discarded because of changes. In these

circumstances, simultaneous management is required to make stable decisions. Managers need both an inward and an outward orientation to keep abreast of the situation. They must rely on both formal and informal actions and structures. As the situation unfolds they swing between reflection and action.

VII. Pieces of the solution.

While the dimensions of uncertainty, complexity and quickness characterize LANL projects, the degree experienced on each project varies. No one solution will be right for all projects. (It is worth noting that research has shown that engineers and managers routinely underestimate the complexity and uncertainty associated with their work when they take on tasks.) In a sense, LANL does not have "a" project management problem. Rather it has the problem of tailoring the project management system to the specifics of the emerging situation on each project. Focus on scheduling and control techniques associated with simple certain projects is only warranted on those projects. At LANL the first area for real consideration is integration.

Integration is one key to effectively managing in complex circumstances. The project organization would be highly integrated if: 1) objectives and constraints were adequate and understood; 2) decisions in various parts of the organization were coordinated in time; 3) common units for planning doing and controlling cost of work were established and used; and 4) feedback on decision quality, remaining uncertainty, and downstream performance was available and used for control and learning. In practical terms, integration requires early involvement of construction expertise, DOE and Engineering Management and continued high level client involvement throughout the project.

How can integration be achieved? Should ENG-1 provide the central coordination or should each client build its own project management organization? While a rule based hierarchy may be able to establish some degree of integration, it is difficult when the rules keep changing. Likewise, the competitive pressure of market forces will work against integration if the competitive boundaries are not carefully drawn to assure the correct people are working cooperatively.

The issue of integration is related to the project delivery role of the CPM. When projects are simple and certain, the CPM can act as middle level managers carrying out orders from clients. When projects are complex and uncertain, the CPM will serve more as a negotiator working between the client, various

authorities, including ES&H, and the contractors. As much as clients would like to have them function as executors of defined plans and ENG-1 would like to be an agency with the power to get things done, in most cases the CPM is a negotiator working to achieve integration, and not an authority with the power to enforce rules. The CPM themselves complain that they lack the authority to carry out their assignments and priorities are undefined.

Part of the priority problem is related to the evolving LANL mission and part due to conflicting requirements from within various offices of DOE. LANL itself is not a single entity with clear priorities which bind the various directorates. Efforts to define a unified set of priorities have done little to change this situation. Lacking unified priorities, it is difficult for CPM to determine the most important tasks and to shift resources to meet most urgent requirements. The problem is intensified when the CPM must work with other regulating agencies such as ES&H. Here each CPM must try to convince another overloaded person that their particular project is of utmost importance. Having no position of relative authority and no mutual goals, these exchanges are difficult. The CPM can make their case, try to appeal to some vague authority or take the "regulator" to lunch.

Locating the CPM function in the client organization and defining it as the "Owner's Project Manager" as defined by the Construction Industry Institute may force the clients to identify their priorities but this will have little impact on the priorities of other participants such as ES&H regulators (Attachment 1). Since unified priorities for all projects at LANL seem unlikely, the location of the CPM is not as important as clearly understanding the facilitative nature of their job. The CPM as facilitator needs training in negotiating and process management skills, and the establishment of appropriate coordination meetings.

While there are larger flow charts of the project process which reflect key decisions and major milestone activities in the process, the steps within the activities are not sequential. CPM report significant time chasing between various agencies trying to determine what can be done and responding to evolving technology, regulations, and hidden problems. This process is made more difficult because management's priorities are not clear and people and resources are scarce.

In the past CPM have been assigned "cradle to grave" project responsibility. This means that they must work on developing projects while managing the day to day operations of projects in construction. The proposed shift to teams suggests that the team leader must be the one responsible for

overall project success. Teams organized by clients make possible the joint planning sessions mentioned above. Further advantage can be gained by specialization within each client team. Different people can and should be assigned to work in development and in the construction phase. (The start of detailed design may be the best place for the baton to be passed.) But a warning is in order. When projects are broken into pieces, someone - the project manager - must be watching the details and the big picture.

How much uncertainty exists at each stage in the process? It is reported that uncertainty first appears in small details such as how a SWMU will be classified. Recent research suggests that significant uncertainty exists on 80% of all construction projects as late as the start of construction. There is little to suggest LANL projects are different (and a lot to suggest they are less certain). Projects built to support basic research, weapons technology and evolving environmental requirements are likely to be defined by uncertainty. The current approach to funding which establishes hard dollar constraints prior to detailed design, coupled with the annual release of funds, effectively assures significant inherited uncertainty and removes down stream flexibility. It is unlikely that the management of these projects will benefit to any great extent in the early phases from the simple application of downstream scheduling techniques. Rather, engineering management must take on the task of improving the stability of decisions - in the face of a shifting environment and their own lack of control of the larger issues affecting projects. Both clients and service deliverers hate to admit uncertainty and current project management literature offers little advice for the effective management of projects under uncertainty.

VIII. Recommendations.

Recommendations are offered to make the best of the current situation and to use LANL project management as a test bed to learn more about managing contending demands.

A. Implement the proposed changes within ENG-1. In particular consider changing from assigning a single CPM to a project for the duration to dividing the process into two phases. The first or project development phase ends with KD2 at the start of detailed design. The team leader is then responsible for project delivery and must coordinate the hand-off of projects. The division of work at this level will allow the more senior managers to spend more time scanning the external environment and anticipating emerging trends. The key here is to make certain that the team leaders understand that their job is to assure

stable decisions. This means lifting their attention to broader issues.

Divided responsibility may conflict with the "cradle to grave" concept preferred by DOE but it is unlikely that any one person could have or develop all of the skills needed to manage a project over its life. (CPM should spend some time in both development and construction roles for career development.) It is equally unlikely that the CPM will be given the authority to direct projects. Negotiation training will help the CPM and joint negotiation training sessions with regulators should be considered.

B. Assure the project process is understood and accepted by all involved. As a first step gather LANL, Client, ES&H, LAAO and ENG representatives. Use this group in a TQM like effort to determine if steps described in the Project Handbook for each project funding situation are currently being followed. The group can then determine 1) the primary directives or requirements for each step, 2) the extent to which the processes within each box are a routine sequence, 3) the causes of variation from the prescribed process. This group may be able to identify when the current organization and management approaches lead to CPM focusing on the wrong things.

C. The development of teams within Engineering makes possible project process planning meetings throughout the life of a project. While there is little support for more meetings in most organization, there exists no clear alternative. Computer Groupware and Email may help. Better meeting management would not hurt. Some success has been reported at Sandia from assembling relevant project participants for a planning session. These internal "partnering" sessions are effective forums for integrating a project organization. These meetings offer the larger project community a chance to see both the big picture and the details.

D. Implement a charge-for-service system. Bringing market forces inside a bureaucracy can be an effective way to improve services. Charging for services will effect both the client and larger management organization. In so far as the cost of engineering services has been viewed more or less as overhead, it is little wonder that there is a tremendous backlog of work, great effort expended in concept and design stages and a relatively small amount of construction completed each year. Thus the first effect of expanding the recharge system may be to reduce effort expended on marginal projects. While setting LANL priorities may be difficult, it should not be hard for the various directorates to decide if it is worth spending money to develop projects.

Clients may not like to pay for services and may assume that recharge

and the potential for shifting to outside vendors will force the project deliverers to be more productive and responsive. The underlying belief is that market forces will reduce the cost of operating the larger organization by rules. To some extent this may be true but requires the development of a cost capture mechanism to inform Engineering customers. This will work if the pricing structure reflects the cost of bringing a project to completion. If the pricing structure overstates the cost of the Engineering services, clients may assume they can get a better deal outside. On the other hand, if the pricing function underestimates the expense, clients may use Engineering services on marginal or unlikely projects.

Market transactions can contribute to reduced costs when buyers and sellers can use prices to make decisions on alternatives. A pricing mechanism promotes efficiency because it gives clients the basis for choosing external suppliers. The price charged for services must accurately reflect actual experience if there is to be any benefit from charging for services. DOE requirements to limit charges to some projects while requiring ENG-1 to recover all costs from other clients distorts the situation and will not result in more efficient management. Overstated prices will defeat the promotion of efficiency by distorting the decision making processes. Total project costs will increase if clients can choose outside suppliers based on the mistaken belief that similar services from ENG-1 are more expensive. Likewise, clients will tend to mistakenly favor outside contractors if contract administration costs are not identified and charged. The current LANL practice of charging a flat rate for in-house and contract support tends to minimize job-shopping, but may increase pressure to establish independent contracts to support line divisions outside the recharge mechanism.

Given the uncharted complexity of project development, it makes sense to initially restrain the urge of clients to hire outside contractors to manage project development until the process is stable and the rules more predictable. The degree of uncertainty associated with project development would make it difficult for contractors to accurately estimate their risk and define their costs for fixed price contracting. Relying on outside contractors to provide development services on a cost plus basis offers little advantage over relying on the existing ENG organization.

Allowing clients to contract management services for detailed design and construction is probable never a good idea. While ENG-1 must develop an experience base to identify the actual costs of managing detailed design and construction with in house CPMs, there will be no advantage to the government if charge-for-services destroys in-house capability and simply moves the CPMs into

the private sector where the limited number of suppliers will charge more for the same services.

E. Since it is unlikely that LANL will rely completely on market forces to identify project priorities (This could lead to different directorates bidding for the services of ES&H), some rough priorities must be determined and a system of re-determination and communication established. This cannot be done within any one client or within Engineering. Given the difficulty of keeping abreast of 200 plus projects and the difficulty of ranking every project some brute force technique should be tested. One approach would be to have priority of clients or programs set by LANL and then have the clients set the priorities for projects within their area. Another approach would be to identify the top 10 projects at LANL and then rank all remaining into three groups - top, middle and bottom. Whatever is chosen, the priorities must be published so all parties will have the same understanding. There can be little basis for criticizing how CPM set their priorities if there are no priorities given them.

F. Develop project related organizations within each client and regulation group. Within the client organizations an "Owner Project Executive" (OPE) must be identified for each project. This person must be senior enough to develop and maintain agreement within the client organization on project objectives, scope and design basis. This function cannot be delegated to the CPM (the Owner's Project Manager). The CPM must not accept the assignment to try to "glue" the owner together. Rather their job should be to work with other agencies to develop and then to construct the project. Given the uncertainty associated with projects at LANL, the CPM and OPE will have to work closely.

The regulators must be involved in planning the details of the development process for each project. This will reduce or eliminate the need for CPM to threaten or seduce regulators. Regulators must no longer be treated as obstacles.

G. The problems of uncertainty, complexity and speed of delivery must be faced. Many of the current problems stem from the dilemmas caused by uncertainty. Stable decisions will require more careful consideration of uncertainty. LANL can serve as an important test and development site for improving theory and techniques for managing construction in an uncertain environment. The emerging research interest in managing complex adaptive systems could be tapped. One of the most promising techniques is called the DIDA approach which includes four steps: Diagnosis, Information-gathering, Deferring and splitting decisions, and Absorbing uncertainty. This approach is

described in detail in attachment 2. As a minimum, a one day workshop on managing projects which are uncertain, complex and quick should be organized.

H. The TQM team should consider becoming involved in the "Last Planners Research Project." This effort, managed by faculty from UC Berkeley and UNM is designed to identify the resources needed by last planners - those who make assignments, and to realign systems to assure needed resources are available. The research approach is to 1) examine the planning circumstances of last planners in a number of organizations, 2) compare notes between organizations, 3) propose solutions, and 4) implement changes.