OFFICE OF ENERGY RESEARCH

PROJECT PERFORMANCE

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INTRODUCTION

This paper presents case histories of selected projects. These cases set the context for the present Office of Energy Research (ER) Project Management Performance Goals and Techniques. It briefly addresses reasons for good performance in the past and describes a plan which aims to recapture the excellent performance on earlier high energy physics projects. Recent examples cited and the concepts described have been developed over the past 5 years.

EARLY HIGH ENERGY PHYSICS PROJECTS

Table 1 shows summary information on three of the major high energy physics projects completed in the 1960s and 1970s. The original Stanford Linear Accelerator, the original Fermilab accelerator, and the Positron Electron Project at the Stanford Linear Accelerator Center (SLAC) were all completed on schedule, met performance specifications, and were within (or under) the total estimated cost. This performance was excellent.

RECENT "WORST CASE" ER PROJECTS

In Table 2, summary data for some recent "worst case" ER projects is displayed. Here the average CE/IE (completion estimate divided by the initial estimate included in the first construction project data sheet submitted to Congress) is 1.6. This means that, on the average, for this list of "worst case" projects the completion cost, or estimated completion cost (in the event a project was not completed), was 60 percent greater than the initial estimate.

These cost increases were due to several reasons. For the Tevatron I project, the electron cooling concept did not work as planned and a different technology, namely that of stochastic cooling, had to be adopted. This resulted in an approximate doubling of the cost.

Although the Isabelle/CBA (Colliding Beam Accelerator) project was not completed, it has been included in the list with a CE equal to an updated estimate to complete. This estimate was reviewed in detail after Brookhaven National Laboratory (BNL) had clearly demonstrated the ability to successfully produce superconducting magnets using cabled superconductor rather than the original braid concept. The nearly 50 percent increase in the estimate to complete was due to underestimating the cost of producing superconducting magnets and underestimating the inflation which was experienced during this period.

The TFTR (Tokamak Fusion Test Reactor) was built at a time when the schedule was held at a premium and major efforts were made to involve industry in providing as many complete systems as possible. Significant cost increases were encountered on the conventional facilities due to the extreme "fast tracking" of the design and construction activities implemented to meet the tight schedule goals. Perhaps an alternate procurement scenario, wherin some of the more complex operations were performed by the laboratory, may have been less costly, but would not have involved industry to the full extent desired.

The MFTF-B (Mirror Fusion Test Facility-B), comprising two "mirror" end cells and a central solenoid was more than a doubling of the scope of the "single mirror cell" MFTF project. At the time the original MFTF project was approved, it was known that such a modification in scope might be forthcoming and, in fact, the Fusion Mirror Community was encouraged to aggressively develop Q-enhancement (Q = power gain) concepts. Therefore, some program personnel feel it is unfair to include MFTF in this list. Nonetheless, it has been included, since in some circles (see General Accounting Office (GAO) report below) the Department is judged on such a basis.

Such cost increases might be considered unacceptable. However, it seems instructive to at least look briefly at part of the "universe of projects" around us before drawing conclusions too hastily.

In each of the cases listed in Table 2, a rather complex device utilizing high technology is being built. This is important to note because ER's and DOE's performance is compared with that of other organizations, some of which construct less complex facilities.

For example, the first comparative project listed is the Hart Senate Office Building. A page from the 1982 General Accounting Office Report on Project Performance in the Federal Government (NSAID-83-32) is shown in Table 3. As noted on the figure, the CE/IE ratio for this project was nearly 3.

This was a building, not a high technology project. It is clear that what are considered by many scientists and other technical people as "straightforward," "brick and mortar," conventional type projects can also be subject to large overruns. Therefore, special techniques and discipline must cover this portion of any ER construction project effort as well as the higher technology or more complex portion.

1982 GAO REPORT ON PROJECT PERFORMANCE (NSAID-83-32)

A summary page from the above referenced GAO report is shown in Table 4. The summary report data has been augmented to show CE/IE ratios for several of the agencies listed.

First, we note that the DOE-wide CE/IE ratio is 2.5. On the average, projects in DOE, in the same timeframe as those on the ER "Worst Case" Projects list, overran more than the ER "Worst Cases."

However, we note that the Department of Defense-wide (DOD) CE/IE ratio is almost 5. Furthermore, of the six Federal agencies listed with more than $10B of construction underway, DOE has the best performance.

SPECIAL CASES OF PROJECTS WITH LARGE OVERRUNS

Table 5 shows the CE/IE ratio for the Alaska Pipeline, as well as the average ratio for five listed nuclear power plants. In the case of the nuclear power plants, one of the individual ratios is greater than 15.

SUMMARY OF SELECTED PROJECT PERFORMANCE

A summary of the selected project performance discussed above is presented in Table 6.

It might be concluded from this summary that ER Project Performance is, in fact, quite good. Even the performance for the recent ER "worst cases" looks good in comparison to other entries in the Table. This seems especially so in light of the high technology nature of many of the accelerators and devices which are constructed in support of the ER programs.

ER PROJECT PERFORMANCE GOALS

One might ask, "Why worry about improving performance which is already quite good?"

A strong driver in answering this question stems from the nature of Federal funding for science and basic research in the United States. Over the last few years, such funding has been fairly constant. In the case of Fusion, it has declined significantly. In the face of flat funding, 60 percent cost overruns on large construction projects can siphon funds from the ongoing programmatic research and do material damage to these ongoing programs.

To avoid the implementation of catastrophic management actions and reprogramming of funds, the required resources for completing construction must be estimated much more accurately and the projects must be managed in such a way to be completed within the planned resource profiles. This, then, is the reason ER wishes to improve in the area of construction project performance.

MOTIVATION, THE KEY INGREDIENT IN PROJECT MANAGEMENT

Given the selected project history sketched above, one might also ask the question, "How or why has ER project performance proceeded so well?"

An attempt is made to explain this phenomenon with the help of Figure 1 where a simplified diagram of the construction process is shown. The "inputs" to this process are people, ideas, and materials. In the case of ER projects, the "outputs" are laboratory facilities, accelerators, and research devices. The concept of "management" is depicted in Figure 1 as a feedback loop where samples of the output are taken and guidance, redirection, or corrective action is taken to modify the construction process in a manner so that the desired output is attained on schedule and for the expenditure of only the planned resources. The management actions depend on the motivation, skills, knowledge, and abilities of the management personnel and project staff. It seems that the motivation of the management may, indeed, be the primary factor in successful or "good" project performance.

It must be noted that, for projects where the respective nonprofit laboratory or university management is held primarily responsible for managing and completing the project successfully and within the planned resources, management has a special incentive to complete the project for the planned resources because overruns result in reducing resources for the ongoing scientific program. A current example of such a highly motivated project management is that of the SLAC Linear Collider (SLC) project, where the Director of the Laboratory, Dr. Burton Richter, is the primary proponent of the SLC project and at the same time is charged with managing the high energy physics research program. This same degree of management motivation does not necessarily exist in other organizations and could well explain the larger project cost overruns experienced.

In the case of projects where most of the procurement is done directly with the private sector and where profit is the primary factor in motivation, the same management incentive to complete projects within the planned resources is absent. Therefore, the CE/IE of 5 or more for some projects without the aforementioned special motivation is not too surprising.

ER PROJECT MANAGEMENT SYSTEM/TECHNIQUE

Given the ER project management goal of estimating the required resources for ER projects accurately and managing these projects in a manner to complete them successfully within the planned funding profiles, what management system or technique is applied to achieve this goal?

The construction process shown in Figure 1 is referenced again in describing the ER Project Management System. The system consists of 1) establishing technical, cost, and schedule baselines; 2) tracking performance against those baselines through monthly reports and twice yearly Technical/Cost/Schedule/and Management Reviews; and 3) utilizing the management feedback loop to modify the construction process so that the baselines can be met. There is the additional concept of planning an additional amount of funding resources, called contingency, beyond the basic estimated cost for the project to allow for errors and omissions in the basic estimate, uncertainties in the estimate due to developmental aspects of the project, and to provide some flexibility for accommodating other "unknowns" at the time the baseline cost estimate is prepared. DOE Operations Office personnel, located at the site for large projects, carry out the day-to-day project management oversight on ER projects. A Project Management Plan is developed at the beginning of the project which describes the project in some detail; sets forth the technical, cost, and schedule baselines; names the parties to be involved in the design, construction, testing, and commissioning of the project; their relationship(s) to each other; and the plan for accomplishing the project, including change control mechanisms for modifying the baselines and managing contingency.

The twice yearly reviews are conducted by DOE Headquarters and field office personnel, along with selected technical experts from other laboratories, universities, and industry. Special agenda are agreed upon prior to the review, updated and detailed estimates to complete the project which incorporate experience to date and new information are prepared, the review is conducted, and executive closeout sessions are conducted during which Review Committee Findings and Conclusions are presented to Project Management and Action Items for laboratory and DOE personnel are agreed upon.

In summary the ER Project Management System (Table 7) continues to rely on the highly motivated laboratory and/or university management with the addition of Technical/Cost/Schedule Baselines, Change Control Procedures, Operations Office oversight, Technical/Cost/Schedule/and Management Reviews, and the planning for and provision of contingency funding.

It is felt, that through the application of this system or technique, the record of ER project performance can be improved and that the earlier CE/IE ratio of ≤ 1 might be once again attained.

TABLE 1

Source: W.K.H. Panofsky
May 28, 1980

RECORD OF LARGE EARLY HEP PROJECTS

Device	Site	Construction Start	On Schedule	Specifications	Cost Estimates	Cost in Then Yr $'s
Proton-Synchrotron	FNAL	1969	Yes[1]	Exceeded	Under 3%	243,000,000
2-Mile Linac	SLAC	1962	Yes	Exceeded	Met	114,000,000
PEP	SLAC	1976	Yes	Met[2]	Met	78,000,000

1 Three months ahead of original schedule.

2 Final performance not yet established.

GOOD!

TABLE 2

Prepared in September 1983

ER PROJECTS WITH INCREASED TEC'S

	TEC ($ In Millions) Initial	Current	
High Energy Physics			
CBA (Isabelle)	275	473.3	(First Sextant R&D)
Energy Saver	38.9	50.8	
Tevatron I	41.5	82.5	
SLC	112	115	
Fusion			
TFTR	215	314	(Minor Descope)
LCTF	18	35.7	
MFTF-B	94.2	243.2	Major Upscope
EBT-P	(25) 44	97.8	
FMIT	85	105	
	924	1517	

$$\frac{\text{CURRENT}}{\text{INITIAL}} \approx 1.6$$

Not As Good

Source: GAO Report NSIAD-83-32
"Status of Major Acquistions as of
September 30, 1982"

ACQUISITION STATUS SUMMARY AS OF SEPTEMBER 30, 1982
(DOLLARS IN MILLIONS)

Agency: Architect of the Capitol

Project Name ID#/Category/LOC/Quantity	Total Estimated Cost: Current Estimate	Total Estimated Cost: Change From Development: Amount	Total Estimated Cost: Change From Development: %	Federal Share of Estimate: Current Amount	Federal Share of Estimate: Change From Initial Est: Amount	Federal Share of Estimate: Change From Initial Est: %	Federal Share of Estimate: Change During Fiscal Yr. 82: Amount	Federal Share of Estimate: Change During Fiscal Yr. 82: %	Unit Cost: Amount (in $)	Unit Cost: Init % Chg	Qnty % Chg	% of Fundg Rcv'd	Yrs Slip
Hart Senate Office Building 523 /Other /DC/1020000 Gross SQ F	138.0	52.9	62	138.0	90.0	188	0.3	0	135	187	0	100	6.2
Subagency Total	138.0	52.9		138.0	90.0		0.3						
Agency Total	138.0	52.9		138.0	90.0		0.3						

48 → 138

$$\frac{CE}{IE} = 3$$

Source: GAO Report NSIAD-83-32
"Status of Major Acquistions as of
September 30, 1982"

TABLE 4

MAJOR ACQUISITIONS AS OF SEPTEMBER 30, 1982 (DOLLARS IN MILLIONS)

Agency Name	Total Ongoing Acquisitions		Acquisitions Having Cost Growth				Agencies Over $10B (Dollars in Billions)		
			Development Est		Initial Estimate				
	No. Acqs.	Current Estimate (CE)	Amount	Growth	Amount (IE)	Growth	Current Estimate (CE)	CE/IE	Rank
Architect of the Capitol	1	138.0	85.1	52.9	48.0	90.0			
Army Corps of Engineers	97	24852.0	15343.2	6569.1	6878.4	15063.0	$ 24.9	3.6	4
Health and Human Services	2	175.0	56.6	24.4	56.6	24.4			
Department of Justice	1	65.0	57.2	7.8	55.4	9.6			
Department of Commerce	6	1797.0	996.4	751.6	1035.1	712.9			
Department of Defense	173	741832.0	183036.2	364416.3	152828.3	414684.9	741.8	4.9	5
Department of Energy	57	29302.3	11501.5	3895.0	11663.0	11012.2	29.3	2.5	1 ←
Department of Interior	32	13088.0	4670.7	8053.3	4664.2	8066.1	13.1	2.8	3
Department of Transportation	32	13632.0	4136.1	6422.9	5228.4	2129.6	13.6	2.6	2
General Services Admin.	2	167.0							
National Aero. & Space Admin.	0	3320.0	1655.3	869.7	1685.0	925.0			
Pennsylvania Ave. Devlp. Corp.	1	279.0	223.0	56.0	223.0	56.0			
Department of State	1	96.0	85.6	10.4	85.6	10.4			
Department of the Treasury	2	177.2			100.0	3.0			
Tennessee Valley Authority	15	11804.0	1586.0	9110.0	1976.0	9171.0	11.8	6.0	6
Veterans Administration	14	1639.0	644.0	641.0	643.8	641.2			
Grand Total	444	842363.5	224076.9	400880.4	187170.8	462599.3			

DOE Ranks #1 of 6 Agencies W/>$10B Construction

#2 in Total Cost of Construction Underway

$\frac{CE}{IE}$ = 2.5 Not Good?

Not Bad!

Source: USA TODAY, Page 3A, January 12, 1984

TABLE 5

SOME NUCLEAR POWER PLANT COST OVERRUNS

	IE	CE	CE/IE
Marble Hill, Indiana	$ 1.4B	$7.7B	5.5
Shoreham, Long Island, NY	261.0M	4.0B	15.3
Midland, Michican	350.0M	4.4B	12.6
Zimmer, Ohio	240.0M	3.0B	12.5
Seabrook, New Hampshire	973.0M	5.8B	6.0
			[10.4]

Alaska Pipeline $7B/$.9B = 7.8

TABLE 6

SELECTED HISTORY OF PROJECT PERFORMANCE

	CE/IE*
Early HEP Projects	1.0
Recent "Worst Case" ER Projects	1.6
Recent DOE-wide Projects	2.5
New Senate Office Building	3.0
Recent DOD Projects	5.0
Alaska Pipeline	7.8
Recent "Worst Case" Nuclear Power Plants	10.4

* CE/IE is the ratio of the current (or final) estimate to complete to the initial estimate. For government agencies the IE is taken to be initial formal request for funds from Congress.

TABLE 7

ER PROJECT MANAGEMENT SYSTEM

— HOLD RESPECTIVE LABORATORY OR UNIVERSITY MANAGEMENT PRIMARILY RESPONSIBLE FOR MANAGING AND COMPLETING PROJECTS SUCCESSFULLY AND WITHIN THE PLANNED RESOURCES.

— KEY ELEMENTS OF THE "SYSTEM"

1) ESTABLISH TECHNICAL, COST, AND SCHEDULE BASELINES,

2) TRACK PERFORMANCE AGAINST THOSE BASELINES THROUGH MONTHLY REPORTS AND TWICE YEARLY TECHNICAL/COST/ SCHEDULE/AND MANAGEMENT REVIEWS, AND

3) UTILIZE THE "MANAGEMENT FEEDBACK LOOP" TO MODIFY THE CONSTRUCTION PROCESS SO THAT THE BASELINES CAN BE MET.

— EMPLOY CONCEPT OF CONTINGENCY, THAT IS PLANNING AN ADDITIONAL AMOUNT OF FUNDING RESOURCES BEYOND THE BASIC ESTIMATED COST TO ALLOW FOR:

- ERRORS AND OMISSIONS IN THE BASIC ESTIMATE,
- UNCERTAINITIES DUE TO DEVELOPMENTAL ASPECTS, AND
- PROVIDE SOME FLEXIBILITY FOR ACCOMMODATING OTHER "UNKNOWNS" AT THE TIME THE BASELINE ESTIMATE IS PREPARED

— UTILIZE DOE OPERATIONS OFFICE PERSONNEL TO CARRY OUT DAY-TO-DAY PROJECT MANAGEMENT OVERSIGHT.

FIGURE 1

MANAGEMENT OF CONSTRUCTION PROJECTS