CONTROLLING ACCELERATOR ENGINEERING COSTS

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Summary

Cost control for accelerator engineering involves task definition, planning related expenditures, measuring progress, tabulation of costs and projections, and, most important of all, follow-up for corrections. Accelerator engineering costs are best regulated by the accelerator engineer, since those who are in any way detached from the work cannot exercise the most effective control. The accelerator engineer should be assisted by providing him with an effective system, appropriate forms and reports, and administrative support.

Introduction

An interesting thing about accelerators is that engineering and development costs often approach fifty per cent of the total installed accelerator cost[1] (excluding building and site) whereas engineering of construction projects often is less than ten per cent of total installed cost[2].

Cost control for accelerator engineers is a necessary chore, unpleasant though it may be. However, this chore, when done in a logical manner, can result in economies and may even become a satisfying accomplishment for the engineer, such as when a project is completed for nearly what it was supposed to cost.

The following is a system which works for William M. Brobeck & Associates. Although it seems simple enough, we have found little[3,4,5] in the literature which describes the elements of engineering cost control applicable to accelerator-type projects. So we decided to write about it so that others might profit by it.

Define Tasks

The first step in controlling costs for accelerator engineering projects is to establish definite tasks. We think of a task as a portion of work which can be identified and distinguished from the balance of the work on the project.

A task description should be prepared for each task. Figure 1 is a sample of a task description which defines a task as well as its related account number, responsible engineer, budget, and schedule. Tasks may be organized by different parts of the accelerator facility; or by project phase such as study, model, design, test, etc; or organizationally, by physics, mechanical engineering, electrical engineering, drafting, etc.; or by some combination. It is preferable to tailor the tasks to the particular project. Defining development and study tasks can sometimes be difficult, but it should be possible to define objectives or goals for the task if it is worth undertaking.

The following criteria have been useful guides in establishing suitable tasks. Sometimes all of these criteria cannot be satisfied simultaneously, so comprises often result.

1. Task Boundaries Should be Clearly Defined. There should be a clear-cut distinction between concurrent tasks so that there will be little doubt as to which account number to charge time to. There should be a clear-cut distinction as to start and completion of the task preferably by means of an unambiguous event such as submission of a report. All task requirements should be stated, and sometimes it also helps to explicitly state items which are not included.

2. Task Should be Consistent With Project Objectives. Completion of all tasks should correspond to completion of the over-all project. The total of all task budgets should not exceed the project budget. Task should agree with requirements of contracts and legislation which are applicable to the project.

3. Task Should be of Manageable Size. Budgets of $2,000 to $20,000 have proven convenient for control of engineering tasks.

4. Not Too Many Tasks Should Run Concurrently. It is easier to simultaneously control a few tasks rather than many tasks. From one to ten active concurrent tasks can be reasonably controlled by one engineer. On projects with many active tasks management may prefer to use cost summaries by groups of tasks for project cost control.

5. Tasks Should be of Reasonable Duration. Task durations of two to six months have proven effective when task costs are reported semi-monthly.

6. Task Should be Consistent with Project Organization. There should be only one boss (normally a "task engineer") controlling expenditures on a given task.

7. Task Should Preferably have a Single "End Product". It is easier to control costs of a single "end product", such as a set of drawings or a report, rather than of several items with staggered delivery requirements.

Prepare Task Plan

The next step in controlling accelerator engineering costs is to prepare a task plan which sets forth the anticipated expenditures which are required to achieve the task objectives. Figure 2 presents a typical task report form (Engineering Progress Report) on a format which permits presentation of the task plan plus periodic updating and reporting. The details of the task plan will likely vary to meet the user's requirements. However, the following features have proven useful.

1. Program the different types of expenditures, such as manpower requirements for engineers, draftsman, technicians, etc., plus allocations for consultants, material, travel, telephone, reproduction, etc. that are planned for the task.

2. Program expenditures chronologically, preferably into the same time intervals as used for cost reporting. Use of a simple "bar chart" schedule may facilitate distribution of costs into the selected time intervals.

3. Identify intermediate check-points or "milestones" which can be used to measure progress toward task completion.

Periodically Review Task Costs

The objective of cost control is to hold total expenditures, past plus future, within the budget. A periodic review of costs incurred to date and an estimate of remaining costs to complete should be made. Performing task reviews at monthly, semi-monthly and weekly intervals has been successful. The time interval selected depends to a large extent on the task duration with short intervals being used for short tasks. Monthly intervals are standard.

Actual costs incurred to date should be presented in a timely and useful manner to the project and task engineers who are controlling task expenditures. Accounting groups can usually supply this data. To be most effective, the cost data should be available within a few days of the close of the accounting period.

Data-processing systems can be used advantageously to prepare up-to-date cost reports[6]. However, regardless of whether manual or computer techniques are used, the importance of getting the cost data to the user in a hurry cannot be overstressed. Costs should be reported for each task. Summaries by task groups and for entire projects can also be useful.

Preparation of budget plots[7] (dollars vs. time) to display monthly and/or cumulative expenditures are good for indicating trends and expenditure patterns. These can either be done manually by the "controlling" engineer or done for him on the computer.

Reporting of past expenditures does not necessarily provide good indicators of future costs. For instance, if fifty per cent of the allotted time has elapsed and fifty per cent of the budget has been expended, one might assume that the task was entirely healthy. This is true only if the task will be completed on schedule. It is, therefore, necessary to evaluate the work remaining.

The estimated total cost of a task will vary as the task progresses due to factors such as problems encountered, caliber of people assigned and unanticipated work. A classical method of estimating the work remaining is for someone knowledgeable of the task to make an "educated guess" of the percentage completed. Unfortunately, these guesses often are optimistic and result in a series of completion reports that characteristically approach 100 per cent completion asymptotically.

Rather than directly estimating "percent complete" we have arrived at the conclusion that it is better to estimate the "cost to complete". This can be done by updating the task plan. The task report form (Figure 2) can be used to plan a program for completing the task, to estimate the cost of the plan, to report on problems encountered, and to explain variations from previous plans and milestones. This task report is normally prepared concurrently with compilation of actual costs to date. Reasonable care is required when preparing the task report since effective cost control requires accurate data.

Prepare Useful Cost Reports

Cost data should be presented promptly and in useful form to the engineers and administrators who monitor and control task expenditures. The task engineer should definitely get a copy as he is the individual who is in the best position to control expenditures.

The Project Budget Report shown in Figure 3 is one of the principle tools of cost control at William M. Brobeck & Associates. An IBM 1401 computer is used for its preparation, which permits rapid compilation and reporting of the data.

Input consists of "Budget", "Total Charges to Date", and "Estimated Cost to Complete" for each task. "Estimated Total Cost This Period", is the sum of "Charges to Date" and "Cost to Complete". For comparison purposes, the "Estimated Total Cost - Last Period" and the corresponding "Percent of Budget" are also given. "Percent Complete" is computed as "Total Charges to Date" divided by "Estimated Total Cost". Subtotals are shown for each group of tasks. Similarly, totals are given for the sum of all task groups in each project.

"Warning signs" to watch for in the Project Budget Report are a projected overrun, which is indicated if "Estimated Total Cost Percent" is greater than 100, and adverse changes in "Estimated Total Cost" which are indicated by comparing figures for "This Period" and "Last Period".

Relation To Over-All Accelerator Facility

Engineering is usually only one facet of an over-all accelerator facility. The reporting system just described provides data which can readily be tied into a management control system for the enitre project or facility.

Engineering task costs can be integrated into an over-all cost control system for the entire project or facility.

Task completion dates and milestones can be used for input into CPM[8], PERT[9], or PERT/COST[10] programs for scheduling of over-all projects.

Month-by-month manpower projections given in the task plans and task reports can be used for manpower planning for the over-all facility, perhaps utilizing advanced planning techniques, such as RAMPS.[11]

Follow-Up

Appropriate action should be initiated if expenditures are not under control. Corrective action to put the task back on-budget can be taken if the cost problem is detected early enough. Sometimes the task can be redefined to cover less work. Sometimes more effective personnel can be assigned to the task. Sometimes the work to be performed can be reduced. Sometimes the task engineer plans to do more work than required. Perhaps all that can be done is to inform management or the client that the task will overrun so that they can anticipate the overexpenditure.

Key Role of Accelerator Engineer

The accelerator engineer is the key man to control accelerator engineering costs. He must participate in the foregoing steps if they are to be effective. His technical knowledge is needed to define logical tasks and to prepare the task plan. He is in the best position to estimate cost-to-complete. Finally, he is the one who can most effectively initiate action to get the task back on-budget.

It is our observation that most engineers have an honest desire to keep their work within budget. But since engineers prefer technical work to budgets and controls, best results are achieved when cost control work is made as easy as possible. Reports should be kept simple. Staff support should be provided to assist, but not replace, engineers in preparing task descriptions, task plans, and estimates so that they, the engineers, can effectively control costs without being burdened with administrative details.

References

1. Burleigh, R. J. "Costs and Manpower for the Berkeley 88-inch Cyclotron," Nucl. Instr. and Meth. 18,19, pp. 634-638.

2. Bauman, H. Carl. "Engineering Costs," presented before the American Association of Cost Engineers 1964 Annual Convention, New York.

3. Fuller, Don. Organizing, Planning and Scheduling for Engineering Operations, Industrial Education Institute, 1962.

4. Moranian, Thomas. The Research and Development Engineer as Manager, Holt, Rinehart and Winston, 1963.

5. Rogerson, T. W. "How to Control Engineering in New-Product Development," Product Engineering, March 16, 1964, pp. 102-104.

6. Lee, Lyman S. "Feedback: A Key to Engineering Cost Control," Machine Design, October 8, 1964, pp. 134-139.

7. Kergar, Delmar W. and Murdick, Robert G. Managing Engineering and Research, Industrial Press, 1963, p. 236.

8. Kast, W. G. "Critical Path Method Ideal Tool for Plant Construction," Petroleum Refiner, February 1962, pp. 123-130.

9. NASA - PERT "B" Systems Manual, National Aeronautics and Space Administration, June 1963.

10. IBM PERT COST II Program for the IBM 7090, International Business Machines Corporation, 1963.

11. Moshman, Jack; Johnson, Jacob; Larsen, Madalyn. "RAMPS: A Technique for Resource Allocation and Multi-Project Scheduling," in 1963 Spring Joint Computer Conference, Spartan Books, Inc., Baltimore, Md., 1963, pp. 17-28.

PROJECT TASK DESCRIPTION (Cont.)		JOB: 84-5		Page 2 of 13
TASK NUMBER	ENGR.	DESCRIPTION TITLE UNDERLINED. CONTRACT DESCRIPTION IN QUOTES	BUDGET	START-FINISH
12.18	Bolger	<u>Trim Coil Rheostat Racks</u> Prepare plans, specifications, and cost estimate complete and suitable for bidding and procurement of the rheostat racks, including water manifolds, conductor clamps, and internal bus bars, if any. Engineering 69 hours Designer 30 hours Design Check 9 hours Task includes: a) preparation of bid drawings and specification; b) fabrication cost estimate; c) preparation of bidders list; d) attending bid opening; e) review of bids; f) investigation of low bidder's capability and recommendation g) attend preconstruction conference.	1,510	4/15/65

Figure 1

Sample Task Description

WILLIAM M. BROBECK & ASSOCIATES

ENGINEERING PROGRESS REPORT FOR PERIOD ENDING: FEB 28 1965

Project/Task No. 84-5. 12. 18 Title Trim Coil Rheostat Racks

Start Date 1/15/65 Finish Date 4/15/65 Budget $1,310

Routing	Initial	Date	Distribution			
1. Bolger	RB	3/1/65	X (President) WFB		(Drafting) RLT	X
2. Fredriksson	OKF	3/2/65	X (Gen. Manager) WEW		(Shop) HLG	
3. DJB (Planning & Control)	DJB	3/3/65	(Engrg. Serv.) DMT		(PGM) RTA	X

	Name or Grade	Prev. Period Est.	Prev. Period Actual	3/6	3/13	3/20	3/27	4/3	4/10	Bal.	Hours to go	Rate	$
Engineer	Bolger	8	0						4	4	8	13.35	107
Designer	DSNR 4	40	0					20	10	0	30	7.87	236
Shop													

(Hours/(Cost) ~~Month~~)

Purchase Orders	0
Computer	0
Consultant	0
Travel	0
Total estimated COST TO COMPLETE	343

EXPLANATIONS: (Explain changes in schedule, workscope, and/or anticipated variance with budget.)

Schedule delay occurred due to preceding activity not being completed on time.

Figure 2

Sample Task Report Form

WILLIAM M. BROBECK & ASSOCIATES

WILLIAM M. BROBECK + ASSOCIATES
PROJECT BUDGET REPORT
AS OF - 02 15 65

DATE ISSUED - 03 04 65

1 PROJECT/TASK NUMBER	2 PROJECT/TASK TITLE	3 TASK ENGINEER	4 BUDGET	5 TOTAL CHARGES TO-DATE	6 PCT.OF BUDGET	7 ESTIMATE COST TO COMPLETE	8 ESTIMATE TOT.COST THIS PER	9 PCT.OF BUDGET	10 ESTIMATE TOT.COST LAST PER	11 PCT.OF BUDGET	12 PERCENT COMPLETE
084 05	- A + E SERVICES - 70 IN. CYCLOTRON					PROJECT ENGINEER -	O. K. FREDRIKSSON				
084 05 00 00	GENERAL	O.K.F.	52,000	47,899	92	+ 4,101	52,000	100	52,000	100	92
084 05 12 10	TRIM COILS + LEADS	BOLGER	12,000	11,561	96	53	11,614	97	11,817	98	100
084 05 12 11	TRIM COIL RHEOSTSTS	BOLGER	11,800	10,508	89	1,249	11,757	100	11,757	100	89
084 05 12 12	TRIM COIL P.S. STUDY	O.K.F.	4,300	3,574	83	689	4,263	99	4,665	108	84
084 05 12 13	TRIM COIL P. S.	I SMITH	1,500	1,301	87	199	1,500	100	1,500	100	87
084 05 12 17	CABLE DEVELOPMENT	O.K.F.	1,712	29	2	2,151	2,180	127	1,736	101	1
084 05 12 18	T.C. RHEOSTAT RACKS	BOLGER	1,510	7	0	343	350	23	350	23	2
084 05 12 99	COMPLETED SUBTASKS		89,809	89,816	100	0	89,816	100	89,816	100	100
			122,631*	116,796*	*95*	4,684*	121,480*	99*	121,641*	99*	96*
084 05 13 11	DEE+DEE HANDLING EQU	MYALL	8,500	8,117	95	465	8,582	101	8,563	101	95
084 05 13 12	DEE LINER	MYALL	3,300	2,892	88	465	3,357	102	3,367	102	86
084 05 13 13	RESON.COIL.ELEC+PRB	BOLGER	21,200	21,172	100	715	21,887	103	21,348	101	97
084 05 13 15	INSULATORS	MYALL	1,500	1,306	87	127	1,433	96	1,421	95	91
084 05 13 40	EE FINAL DESIGN	HENDRY	18,000	17,232	96	260	17,492	97	17,441	97	99
084 05 13 99	COMPLETED SUBTASKS		30,936	30,936	100	0	30,936	100	30,936	100	100
			83,436*	81,655*	98*	2,032*	83,687*	100*	83,076*	100*	98*
084 05 14 01	TANK CB+PUMPNG MANIF	MYALL	3,800	7,031	185	36	7,067	186	7,067	186	99
084 05 14 03	PUMPING SYSTEM	O.K.F.	5,100	5,188	102	44	5,232	103	5,179	102	99
			8,900*	12,219*	137*	80*	12,299*	138*	12,246*	138*	99*
084 05 16 02	ION SOURCE GAS SUP.	BOLGER	3,400	1,760	52	634	2,394	70	3,189	94	74
084 05 16 03	ION SOURCE POWER SUP	I SMITH	1,700	1,758	103	58	1,816	107	2,458	145	97
084 05 16 99	COMPLETED SUBTASKS		5,279	5,279	100	0	5,279	100	5,279	100	100
			10,379*	8,797*	85*	692*	9,489*	91*	10,926*	105*	93*
084 05 17 01	BEAM PROBES	BOLGER	3,000	832	28	1,317	2,149	72	2,482	83	39
084 05 17 02	BEAM DEFINING SLITS		1,590	138	9	0	138	9	141	9	100
084 05 17 03	BEAM PULLER	MYALL	9,500	6,218	65	3,882	10,200	107	10,120	107	61
			14,090*	7,188*	51*	5,299*	12,487*	89*	12,743*	90*	58*
084 05 18 01	CONTROL POLICY	I SMITH	5,200	4,998	96	216	5,214	100	5,214	100	96
084 05 18 02	CONTROL ROOM PANELS	I SMITH	8,500	7,018	83	1,480	8,498	100	8,498	100	83
084 05 18 05	RACK+PANELS WIRING	I SMITH	6,200	6,068	98	403	6,471	104	6,174	100	94
084 05 18 06	MAGNET CONTROLS	I SMITH	5,000	4,597	92	723	5,320	106	5,226	105	86
084 05 18 07	VACUUM CONTROLS	I SMITH	4,300	4,016	93	331	4,347	101	4,336	101	92
084 05 18 08	RF CONTROLS	I SMITH	4,800	3,280	68	1,584	4,864	101	4,864	101	67
084 05 18 09	COOLING CONTROLS	I SMITH	2,800	2,556	91	250	2,806	100	2,821	101	91
084 05 18 10	ION SOURCE CONTROLS	I SMITH	3,300	839	25	1,295	2,134	65	2,213	67	39

+ ESTIMATED BY CONTRACT ADMINISTRATOR

Figure 3 - Project Budget Report