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Application of a Cost/Performance Measurement System on a Research Aircraft Project

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APPLICATION OF A COST/PERFORMANCE MEASUREMENT SYSTEM

ON A RESEARCH AIRCRAFT PROJECT

James J. Diehl

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SUMMARY

Formal approval to proceed with the procurement of two Tilt Rotor Research Aircraft was received by Ames Research Center in the Fall of 1972. The jointly funded and managed NASA/Army program would be accomplished by an Aircraft Contractor selected by a Source Evaluation Board. The use of a formal Cost/Performance Management System was not envisioned at project initiation but evolved as a result of the winning Contractor's proposal. This paper briefly presents the fundamentals of the Cost/Performance System used, the Contractor's reporting system, the Government Project Office's analyses, and the use of this type of reporting system and recommendations concerning the use of like systems on future projects.

INTRODUCTION

In the Fall of 1972, formal approval was received by Ames Research Center to proceed with procurement of two Tilt Rotor Research Aircraft. The project was to be jointly funded and managed by NASA and the U.S. Army Research and Development Laboratories, with the actual design, fabrication, and initial testing of the aircraft to be accomplished by an Aircraft Contractor, which would be selected after formal competition. The use of a formal Cost/Performance Measurement System was not envisioned at project initiation, but evolved as a result of the winning Contractor's proposal; that is, a cost/performance system was proposed by the winning Contractor and was accepted by the Government. This paper will briefly describe: (1) the fundamentals of the Cost/Performance System used, (2) the Contractor's reporting system, (3) the Project Office analyses, (4) the usefulness to the Government of this type of reporting system, and (5) recommendations for the use of similar systems on future projects.

Throughout the paper, the term Project Office will mean the Government Project Office located at NASA-Ames Research Center. The Contractor's Project Office will be referred to as Contractor. Abbreviated terms will be spelled out the first time they are used. A glossary of terms unique to the Cost/Performance System is provided as the appendix.

PROJECT BACKGROUND AND INITIATION

Contracts were awarded on October 20, 1972 to Bell Helicopter Company and Boeing-Vertol Company for detailed analyses, preliminary design, and program planning (Phase I). The final reports of these contracts were firm proposals for the detail design, fabrication, and flight test of the aircraft (Phase II). Phase I was a three-month effort with the final reports (proposals) received in January 1973. A formal Source Evaluation Board (SEB) was convened at Ames Research Center and was charged with responsibility for reviewing each company's proposal and providing the NASA Administrator (the Selecting Official) with their recommendations. The evaluation was completed, and in April 1973 Bell Helicopter Textron (BHT) (formerly Bell Helicopter Company) was selected. Negotiations began at this time, and the formal contract award for Phase II was made on July 31, 1973.

Prior to the award of the Phase I contracts, each contractor was given a detailed Statement of Work (SOW) which was the basis for their Phase II proposal. Included as part of this SOW was a proposed reporting system for the project. The reporting system was based on the NASA 533 series of cost reports and included, as an option, the NASA Form 533P (Contractor Performance Analysis Report, ref. 1). The detailed reportable items on both the NASA Form 533P and the other NASA 533 reports were based on a Project Office Work Breakdown Structure (PWBS) which was also included in the Government SOW.

The PWBS included in the Phase I SOW is shown as figure 1. Each contractor was told that they must prepare plans and schedules for the conduct of Phase II in strict accordance with the PWBS. They could submit additional plans and schedules keyed to a different WBS. With minor exceptions, the contractors adhered to the PWBS.

PHASE II

Source Selection - System Description

As stated above, Bell Helicopter Textron (BHT) was selected to perform Phase II of the Tilt Rotor Project in April 1973. As a part of their Phase II proposal, BHT proposed the use of their new Management Control System (MCS) for the Tilt Rotor Contract. The MCS was developed by BHT to provide a single integrated system for cost/performance control which would serve the needs of company management and at the same time provide the capabilities necessary to satisfy Department of Defense cost reporting requirements established in DOD Instruction 7000.2 Cost/Schedule Control System Criteria (C/SCSC, refs. 2 and 3). During negotiations the Project Office determined that while BHT could report to the Government using the NASA 533 formats, these would not be the reporting formats used to report to company management. Therefore, the decision was made to drop the NASA 533 reporting requirements except in the top summary levels (level 2 of the WBS) and use the MCS systems as the primary contract reporting system. The advantage of this approach was that BHT could tailor their planning and control system to the manner in which they assign responsibility for carrying out the work. The Project Office did not tell BHT how they should fashion their internal control system, but by using a negotiated Contract Work Breakdown Structure (CWBS) established the criteria that would meet the Project Officer's requirements.

During negotiations, a CWBS (fig. 2) was agreed to, and this formed the criteria for BHT's reporting both internally and to the Project Office. After formal contract award (July 31, 1973), BHT was tasked with establishing budgets for each element in CWBS. These budgets constituted the Budget Baseline of the contract and became the mechanism for determining BHT's performance. The Budget Baseline was submitted to the Project Office in December 1973 and was subsequently approved. This baseline became fixed for the term of the contract, with the exception of: (1) a Management Reserve amount (approximately 10%) which was held by BHT, and (2) added/deleted scope to the contract. At any point in time the total baseline plus any management reserve still held by BHT would equal the target cost of the contract. The fixing of a Budget Baseline that could not be changed except by the mechanism mentioned above does away with something that has haunted projects in the past called a Rubber Baseline. This is the practice of replanning through the course of the project in such a manner that each time replanning occurs the previous plan is erased and, in its place, a new plan is developed which conforms to actual performance to date. This amounts to retroactive planning and presents a situation in which an observer, who was not previously involved, would conclude that everything had been satisfactory, had proceeded as planned, and that any problems that were likely to occur would occur sometime in the future. Utilizing the fixed Budget Baseline the original starting point may always be compared with current estimates.

The BHT reporting system was at the WBS element level; however, the Contractor internally planned and budgeted their work down to the level of short-span increments of work called work packages — packages of one, two, or three months in duration. These types of budgets/cost accounts were issued to each functional area (i.e., Engineering, Manufacturing, Tooling, etc.) and contained both man-hour budgets and schedules. Each functional area in turn issued work authorizations to its respective organization. The matrix shown as figure 3 graphically depicts these cost accounts.

Material is scheduled in two phases: commitment and receipt. During the commitment phase the material is tracked by material release. After the material is received, the tracking and application of the material is dependent upon when it is actually used in the contract. That is, material that is not used immediately is held in an inventory account and is not chargeable to the contract until it is actually withdrawn from inventory and in work.

All the budget to the cost accounts need not be distributed at once. There may be a budget for a specific task when it is not scheduled to start for some time. This budget may be held by the BHT Project Manager for issuance at a time closer to when the task is to be accomplished (i.e., undistributed budget). Throughout these various steps, the BHT Project Manager maintains a record of the budgets he has assigned for the performance of work and then he adds up these budgets to: (1) insure himself and the Project Office that he has not issued budgets in excess of the contract baseline plus Management Reserve, and (2) provides himself and the Project Office with some measure of the planned value of the work being performed. If the Project Office is not aware of the budgeted value of the work being performed, they will not be aware of any significant deviation from the budget should it occur.

In summary, the contract target cost is divided between Budgets and Management Reserve. Budgets are issued by the Contractor's Project Manager to Functional Areas and Cost Accounts, and Functional Areas distribute their budget to Operating Departments and Work Packages. Management Reserve is held by the Project Manager.

Work packages are broken into two types: (1) those with a definite end product or result, and (2) those which do not have a definite end product or result. Where an end product or result is known, the work package is given 50% credit of its budget when it is actually started, and the other 50% credit when it is actually finished. Where no end product or result is forthcoming, the total budget is divided by the total scheduled time and the work package earns credit linearly over its total timespan (or level of effort). This is a distorting input to true value of performance to date, and therefore, as few as possible of these types of work packages should be permitted. It is the summation of all work-package credit at any one point in time that equals the planned value of the work performed, or the Budgeted Cost of Work Performed (BCWP). Likewise, it is the summation of the schedule portion of the work packages and the totals of budget that were scheduled to begin or end, that equal the Budgeted Cost of Work Scheduled (BCWS). The last reporting part of the work package is the actual cost that has been expended to date, or Actual Cost of Work Performed (ACWP).

CONTRACTOR REPORTING

The format for reporting to the Project Office under the BHT MCS system is the Cost Performance Report (CPR) (fig. 4). This report shows the three elements of work package summation (BCWP, BCWS, ACWP) discussed above for the current month and cumulative to date for each element of the CWBS. It also shows, in column 12, the budget (Budget Baseline plus Management Reserve) that has been applied, and in column 13 shows the Latest Revised Estimate (the current estimate that the Contractor has generated as to what it will actually take to do the job). Columns 5, 6, 10, and 11, titled Variance, are the calculations of performance. To help explain the variance columns, a figure of a typical series of work packages has been included (fig. 5). All labor on work packages is budgeted in hours. Direct rates and overhead are applied using computer programs. The figure shows that design was scheduled to start on January 9, but did not actually start until January 14. Because it was scheduled to start on January 9, on that date it received 50% of budget as BCWS. As of January 9 BCWS = 50, BCWP = 0, and ACWP = 0. The variance columns would show schedule variance +50. When the design actually started (January 14) it received 50% of budget as BCWP. As the work had not yet been started, there would be no cost variance. On January 14 BCWS = 50, BCWP = 50 (the job had actually started, thus they get 50% of budget as credit) and ACWP would equal whatever had actually been expended. By February 4, the report would read BCWS = 100 (the job was scheduled to be completed), BCWP = 50 (the job was still not completed so they would only get 50% credit), and again ACWP would equal whatever had been expended. The schedule variance column would equal -50 (BCWP - BCWS), signifying that the job is behind schedule. By February 25 the design was complete and the report would look like this: BCWS = 100 (total credit because the job is done), BCWP = 100 (same reason), and ACWP = 150. The schedule variance column would equal 0 (the job is done) and the cost variance column would equal -50 (telling us the job overran its budget by 50). As can be seen during this same period of time, the fabrication effort began. This work package would be accounted for just like design. All functional activities of work packages are summarized, direct labor and overhead rates applied, material dollar, if any, taken into consideration, and the final summation of all work packages on a WBS element reported on the CPR. The equations for calculating the variances are:

Schedule Variance = BCWP - BCWS

Cost Variance = BCWP - ACWP

It should be noted that at program completion, assuming all the work gets done, BCWS will equal BCWP, which will also equal budget. Thus, the ability to project schedule variance is only possible while the work is in progress. At project conclusion there will be no schedule variances. Cost variance can be determined any time during the project. At project conclusion, the cost variance, whether positive or negative, will equal project underrun or overrun, respectively.

In addition to the numerical pages of the CPR, there was attached a narrative analysis of the schedule/cost variances that were required if the variance exceeded a predetermined criteria (i.e., ±10%, or some other agreed to percent). Also, to support the CPR there is a computer listing available which breaks each WBS element down by each functional labor category, each overhead charge, and each material account.

On a quarterly basis the BHT Project Manager requests estimates from each contractor functional organization for the remainder of the work to be done. These estimates, combined with the actuals to date, are the numbers that appear in the column titled Latest Revised Estimate (LRE). By comparing these LREs with the original budget column one can easily identify the problem areas of the Project. The last column on the CPR is the variance or difference between the budget numbers and the LRE.

PROJECT OFFICE ANALYSIS

Now that the major functions of the MCS system and the basic reporting the Project Office receives have been explained, the use the Project Office makes of this material and the part that it plays in project management will be discussed.

The PWBS, and later the CWBS, were designed to establish a means for an orderly tracking of the progress of the Tilt Rotor Project; that is, to separate the total project into small enough increments of work so that technical coordinators (Project Engineers) from both the Government and the Contractor could follow the effort that was taking place. The Project Office Engineers were assigned WBS elements consistent with their expertise. They were charged not only with the technical status of their elements, but also with the schedule and cost status. This approach was taken as it was felt that the technical coordinator would be better aware of what had taken place, or was yet to take place, and be able to render a more objective judgment on budget expended for progress made. Day to day contact with their counterparts at the Contractor's plant, reviews of drawings, specifications, plans, reports, and analyses of technical problems further support this premise. A formal training program was instituted early in the project to familiarize the Engineers with the MCS system. They were not expected to become experts on the system, but to understand it sufficiently to render judgments. Using Contractor reports, they were to: (1) look at the amount of resources consumed by their elements to date (ACWP), (2) determine what portion of the initial estimates were associated with the specific jobs accomplished to date (BCWP), and (3) determine the estimates for the work remaining in their elements (LRE) and amount of resources available to be spent. They were to track their elements in direct labor hours and material (including subcontract) dollars only. Direct labor dollars and overhead rates would be tracked on a total project basis by the Project Control Officer. It was hoped that this approach would alert both the Project Office and the Contractor early to technical, schedule, or cost problems and would provide assistance in identifying the alternatives available for the future. A Project Status Room was established where charts for each active WBS element were maintained (fig. 6). In addition, charts were maintained in this room at the summary levels (levels 1 and 2) of the CWBS and for direct labor rates, overhead rates, functional manpower levels, and engineering drawing releases. The room was maintained so that project management and top Center management could, at any time, review up-to-date status on the project.

PROJECT OFFICE ESTIMATING

Approximately one year after the Phase II contract award, the Project Office became aware that the total effort contracted for could not be completed for the funds that were designated for the contract. This early awareness of a potential overrun can be largely attributed to the Cost/Performance Management System. An analysis technique was derived using the data on the CPRs that enabled the Project Office to complete its own Estimate at Completion (EAC). This analysis has been used over the course of the program with consistent accuracy and has enabled the Project Office to take appropriate steps early enough to lessen the overrun. The details of this analysis technique follow.

The Project Office has been preparing its own "snapshot" EAC for the Tilt Rotor Prime Contract. This analysis uses the Contractor's monthly CPR and projects an estimate at completion based on cumulative performance (in direct labor hours) to date. BCWP, which is a measure of how much scheduled work has been done, is divided by the current budget (also called the Performance Measurement Baseline (PMB)). The PMB is the original budget the Contractor assigned to do a given job plus any Management Reserve that has been added or subtracted for changes to the scope of that work. The resulting fraction times 100 equals the percent complete (since at project completion BCWP will equal the budget). This percentage is then put into the equation

$$\frac{\%\ \text{Complete}}{\text{ACWP}} = \frac{1}{X}$$

ACWP being the actual hours that have thus far been expended to accomplish the work that has been done. At contract completion ACWP will equal the total direct hours expended on the contract. By solving the above equation for X, we get the total estimated hours it will take to do the job based on the current cumulative performance to date and the current level of efficiency. By looking back at figure 5, the example of work-package planning, one can see that the validity of this process could be challenged early in the program because work packages do not receive the full credit of budget (BCWP) until they are complete, but all the while they are being credited with the actual hours expended. One can also visualize, however, that after the contractor has been performing for an extended period of time, and due to the short term of the work packages, the crediting of BCWP will average out. Using the estimated hours calculated by the above method for each functional organization, direct labor and overhead rates from the negotiated Forward Pricing Rate brochure (direct labor and overhead rates are negotiated on a yearly basis between the Contractor and the Resident Government Plant Representative and are used for forecasting future expenditures) are then applied to yield dollars. In the case of the Tilt Rotor Project, material dollars (including subcontracts), which were a major portion of the total contract dollars (37%), were estimated separately. The Project Office generally accepted the total material dollar estimate prepared by the Contractor as there was no qualitative means of determining any inaccuracies. It was felt that this approach was justified as all major subcontracts were submitted to the Project Office for approval and their costs are easily identifiable. The largest major subcontractor, Rockwell International-Tulsa Division (RI-T) (fuselage/empennage), reported to the Prime Contractor in the MCS format. Copies of the RI-T reports were furnished to the Project Office. Further, the Prime Contractor was required to detail all material payments as an attachment to each public voucher that was submitted for payment. Simple addition of the direct labor and overhead dollars plus the Contractor material dollars gave the Project Office an estimate at completion for the contract.

Another method used by the Project Office for estimating total contract cost, utilized the Contractor's cumulative efficiency. This method of estimating started later in the Project (October 1976), at the time the Contractor submitted their first formal overrun proposal. Again, knowing that at project completion BCWP hours would equal the budget hours and ACWP hours would equal the total hours actually expended, by comparing the total budget hours with the total hours in the Contractor's LRE, the projected efficiency for the overall contract in terms of budget could be determined. Using the CPRs for the total project, the Project Office calculated at what efficiency the Contractor had been performing on a month by month, year to year, and cumulative to date basis. Comparing this historical data to the current projection enabled the Project Office to determine if the Contractor was predicting that they were going to get more or less efficient. For the Project Office to project what overall efficiency would be at the end of the contract was a very difficult and subjective task. The approach taken was to look at how many budget hours had been earned and how many were estimated as yet to be earned (budget minus current BCWP to date). Assuming that the cumulative efficiency would get no better or worse, and in fact would remain the same for the balance of the contract, the Project Office was then able to predict what cumulative efficiency would be at project completion.

$$\text{BCWP Remaining} = (\text{Budget} - \text{BCWP to date})$$

$$\frac{\text{BCWP Remaining}}{X} = \text{current year efficiency (no better/no worse projected)}$$

$$X = \text{Estimated ACWP Remaining}$$

$$\frac{\text{Budget}}{\text{ACWP to date} + \text{ACWP Remaining}} = \%\ \text{cumulative efficiency at project completion.}$$

Knowing what the efficiency would be at project completion the Project Office could then compute from the budget and current contractor LRE what the estimated hours would be.

$$\frac{\text{Budget}}{\text{LRE}} = \%\ \text{current efficiency}$$

$$\frac{\text{Budget}}{X} = \text{calculated end of project efficiency}$$

$$X = \text{calculated hours at project completion}$$

Appropriate direct labor and overhead rates were then applied as in the EAC method. Likewise, material dollars were added to get a total contract estimated cost. There are other techniques that may be used in one's analyses of a contract that is being managed with a Cost/Performance System that have not been discussed in this paper but which may be found in references 1 and 2.

CONCLUSIONS AND RECOMMENDATIONS

The primary purpose of a Contractor's Cost Performance Measurement System is to provide the Contractor and the Government with trend information on cost, schedule, and technical problems while they are occurring and while there is time available to make decisions or to take alternative courses of action. The decision to use the Cost/Performance System on the Tilt Rotor Research Aircraft Prime Contract was an excellent one. The complexity of this aircraft and the double-digit inflation that took place during the prime funding years of the contract have certainly had their effect on what the final cost will be. Project Management has not liked the magnitude of the total estimated cost of the Project. However, the early detection of the overrun was made possible because of the Cost/Performance System far earlier in the Project than on past contracts that did not utilize this procedure. Without this system, the total magnitude of these effects would not have been realized until it was too late for Management to take corrective action. Too often in the past, projects have collected vast amounts of information which has simply remained in piles of paper. The Cost/Performance System reports have been utilized extensively, and Project Managers have found they were able to discuss problems based on an analysis of the data. Confidence in the reports and estimating techniques have enabled decisions to be made on major scope changes. The Cost/Performance System is felt to be a worthwhile tool of Project management; however, there are aspects of the system that merit change. As stated earlier, the Cost Account Managers were given budgets for the work in their functional areas. The budgets, however, were in direct hours and material dollars. As no dollar budgets were associated with the direct hours, the Cost Account Managers were not immediately aware of the effect of inflation on labor rates. They were given the false impression that as long as they did the work within the assigned budget hours all was well, not realizing that a ten percent increase in direct rates translates to a substantial overrun when all overheads are applied. It is recommended that the Cost Account Managers be given, not only direct hour budgets, but also dollar budgets associated with these hours. This should afford the Cost Account Manager a better understanding of the financial aspects of the program, and thus give him flexibility to choose the pay category of people to do the job. An apprentice may take longer to do a job but not cost as much as a journeyman (and just the opposite).

As the project draws closer to completion it should be noted that performance in the form of BCWP loses some of its significance. This should be kept in mind and alternate forms of tracking — actual men on the project vs actual work accomplished — should be utilized. That is, when the manpower peaks are long since past and material and subcontract costs have been incurred, it may be wise to track progress differently. It has been found that the greatest benefit of the Cost/Performance System was realized during the highest manpower/cost periods of the project. It is also recommended that the various Cost Account Managers be made equal to, or subordinate to, the Contractor Project Manager. On the Tilt Rotor Project the Cost Account Managers were higher in the Company management hierarchy than the Project Manager. This made the give and take of daily project management operations more difficult.

A Cost/Performance Management System may not be suited for every contract, but it should certainly be considered for those where the complexity of the effort or funding constraints are predetermined to be significant.

APPENDIX

Actual Cost of Work Performed (ACWP) - the actual cost incurred against any work package.

Budget Baseline - the distribution of the contract target cost to Contract Work Breakdown Structural Elements by functional organization.

Budget Cost of Work Performed (BCWP) - the sum of the budgets for completed work packages and completed portions of open work packages plus the equitable portion of level of effort work packages.

Budget Cost of Work Scheduled (BCWS) - the sum of the budgets for work packages scheduled to be accomplished, plus the amount of effort scheduled to be accomplished within a given period of time on level of effort work packages.

Contract Work Breakdown Structure (CWBS) - the WBS that is negotiated and becomes an official part of the contract Statement of Work.

Cost Account - a summary level with the project organization for overall contract planning and control. The cost account represents the functional organization responsibility for work.

Cost Account Manager (Contractor) - the person in the functional organization who is responsible for the overall planning, control, work accomplishment, and performance reporting.

Cost Variance - an expression of the difference between BCWP and ACWP. A positive number means under cost and a negative number means over cost.

Estimate at Completion (EAC) - an estimate prepared by the Government for anticipated total cost of the work when it is completed.

Latest Revised Estimate (LRE) - the anticipated actual cost when the work is completed (prepared by the Contractor).

Level of Effort - a work package that does not have an end product or result.

Management Reserve - that portion of the contract target cost that is not distributed, but which is instead held by the Contractor Project Manager to maintain the ability to fund authorized tasks that were not provided for in the original estimates, or provide additional funds to overrun work packages.

Performance Measurement Baseline (PMB) - the simple addition of the Budget Baseline and the Management Reserve left undistributed.

Project Office Work Breakdown Structure (PWBS) - a WBS created by the Project Office for the Tilt Rotor procurement.

Schedule Variance - an expression of the difference between BCWS and BCWP. A positive number means ahead of schedule and a negative number means behind schedule.

Statement of Work (SOW) - a description of the tasks, products, and/or services to be procured stated as fully, clearly, and precisely as possible. The SOW serves as a basis for contractor response, evaluation of proposals, and source selections.

Work Breakdown Structure (WBS) - a simple family tree-type subdivision of products, components, work tasks, and services required to achieve a desired goal or end product.

Work Package - a detailed task or purchased material item with a cost account. The guidance and budget for a department with a functional organization.

REFERENCES

1. NASA Handbook 9501.2A. Procedures for Contractor Reporting of Correlated Cost and Performance Data. October 1971.

2. DOD Instruction 7000.2. Performance Measurement for Selected Acquisition.

3. Fox, Ronald J.: Development of the DOD C/SCSC. Graduate School of Business, Harvard University.

Level 1 - Tilt Rotor Research Aircraft

Level 2 - Air Vehicle

Level 3 - Fuselage, Empennage, Landing Gear, Ballast System
Wing, Nacelle
Rotors
Transmissions, Cross Shafting
Power Plant
Fuel System
Hydraulic System
Electrical System
Environmental Control System
Emergency Egress System
Flight Controls
Stability and Control Augmentation System
Crew Station
Communication, Navigation, and Flight Instruments
Research Instrumentation
Support Equipment and Systems
Aircraft No. 1 Final Assembly
Aircraft No. 2 Final Assembly
Mock-Up

Level 2 - Test and Evaluations

Level 3 - Component Acceptance Tests
Component Development Tests
Propulsion Systems Tests
Egress System Tests
Integrated Systems Tests
Ground Tiedown Aircraft Tests
Wind Tunnel Aircraft Tests
Post Test Aircraft Refurbishment
Contractor Flight Tests
Government Flight Tests
Simulations

Level 2 - Data and Documentation

Level 3 - Test Plans, Procedures, and Test Reports
Design Reports and Specifications
Inspection and Maintenance Manual
Flight Operation Manual
Instrumentation and Data Acquisition Manual
System Safety Document
R&QA Plan

Level - Spares
Level 2 - Systems Project Management
Level 2 - Training

Figure 1.- Project Office Work Breakdown Structure (PWBS).

Level 1	Tilt Rotor Research Aircraft
Level 2	Air Vehicle
Level 3	Fuselage, Empennage, Landing Gear
Level 4	Fuselage Empennage Landing Gear
Level 3	Wing, Nacelle
Level 4	Wing Nacelle
Level 3	Rotors
Level 4	Blade Assembly Hub Assembly and Controls
Level 3	Transmission, Cross Shafting
Level 4	Left/Right Transmissions Engine Coupling Gearbox Interconnect System
Level 3	Power Plant
Level 4	Engine Power Plant Installation
Level 3	Fuel System Hydrulic System Electrical System Environmental Control System Emergency Egress System Flight Controls
Level 4	Primary Flight Controls Secondary Flight Controls Thrust Power Management System Automatic Flight Controls
Level 3	Crew Station Communications, Navigation, and Flight Instruments Research Instrumentation Support Equipment and Systems Aircraft No. 1 Final Assembly Aircraft No. 2 Final Assembly Mock-Up Analytical Integration

Figure 2.- Contract Work Breakdown Structure (CWBS).

Level 2	Test and Evaluation
Level 3	Component Acceptance Tests Component Development Tests
Level 4	Systems Tests Structural Tests Propulsion Tests Flight Control Mixing Boxes Tests
Level 3	Egress System Tests Integrated Systems Tests Ground Tiedown Tests
Level 3	Wind Tunnel Tests Post Test Refurbishment Contractor Flight Test Simulations
Level 2	Data and Documentation
Level 3	Test Plans, Procedures, and Test Reports Design Reports and Specifications Inspection and Maintenance Manual Flight Operations Manual Instrumentation and Data Acquisition Manual System Safety and R&QA Plan
Level 2	Spares
Level 2	Systems Project Management
Level 2	Training

Figure 2.- Concluded.

Functional Organizations Cost Accounts	CWBS Elements																
	Fuselage	Empennage	Wing	Nacelle	Engines										Manuals	SPM	Training
Engineering	X	X	X	X	X										X	X	
Manufacturing Engineering	X	X	X	X	X											X	
Tooling			X	X													
Logistics															X		X
Manufacturing			X	X													
Quality			X	X													

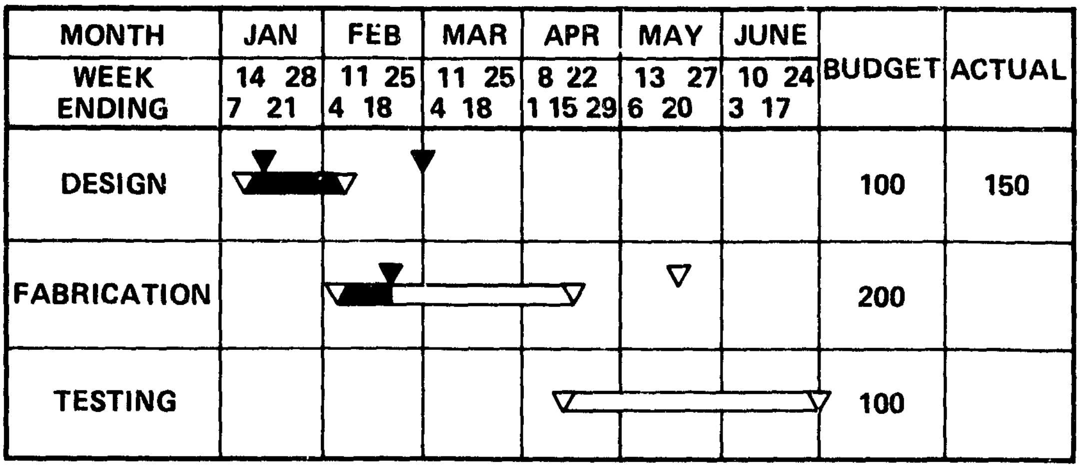
Figure 3.- Cost account matrix.

BELL HELICOPTER COMPANY RDT&E ☐ PRODUCTION ☐	COST PERFORMANCE REPORT - WORK BREAKDOWN STRUCTURE				SIGNATURE of Responsible Mgr. TITLE of Manager DATE of Report
	CONTRACT NO.	PROGRAM NAME NO.	DEFINITIZED CONTRACT	REPORT PERIOD Accounting Month	

ITEM	CURRENT PERIOD					CUMULATIVE TO DATE					AT COMPLETION		
	BUDGETED COST		ACTUAL COST WORK PERFORMED	VARIANCE		BUDGETED COST		ACTUAL COST WORK PERFORMED	VARIANCE		BUDGETED	LATEST REVISED ESTIMATE	VARIANCE
	WORK SCHEDULED	WORK PERFORMED		SCHEDULE	COST	WORK SCHEDULED	WORK PERFORMED		SCHEDULE	COST			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
MANAGEMENT RESERVE EXCLUDING PROFIT/FEE													
TOTAL COST (LESS G&A)													
G & A													
TOTAL													

7874 58801

Figure 4.- Cost Performance Report - Work Breakdown Structure.



NOTE: EACH ITEM WOULD BE A SEPARATE WORK PACKAGE FOR EACH FUNCTIONAL ORGANIZATION.

Figure 5.- Sample work package.

AMES RESEARCH CENTER

RESPONSIBILITY:
APPROVAL
ACCOMPLISHMENT WEIBERG

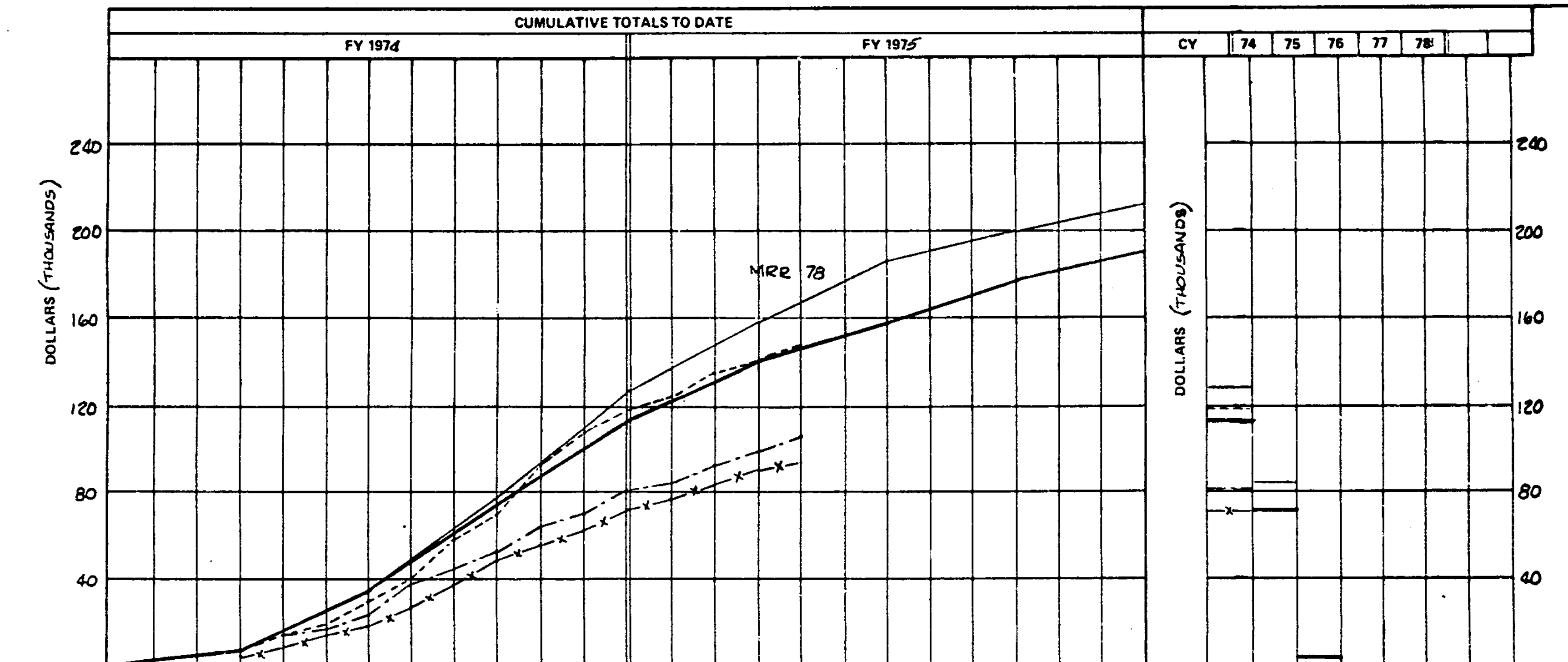
FINANCIAL STATUS

PROJECT: Tilt Rotor Research Aircraft
ENGINE COUPLING GEAR BOX

ADB 412 LEVEL

PLAN LAST REVISED ______

STATUS AS OF 10-31-74



MONTHS	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
NEW PMB			7			35			77			128			159			186			200			213
BCWS			7	15	19	31	40	58	70	92	109	119	125	136	141	148								
BCWP			7	15	18	24	39	45	53	64	69	81	84	93	99	107								
ACWP			5	10	15	19	27	38	49	56	62	72	77	83	90	94								
OLD PMB			7			35			74			114			141			158			177			190

FY	74	75	76	77	78			TOTAL
NEW PMB	128	85	4					217
BCWS	119							
BCWP	81							
ACWP	72							
OLD PMB	114	76	4					194

NOTES:

LEGEND:
NEW PMB ———
BCWS - - - -
BCWP —·—·
ACWP —x—x—
OLD PMB ▬▬

FPR-6

Figure 6.- Project Office Control Room Status Chart.

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16. Abstract

Formal approval to proceed with the procurement of two Tilt Rotor Research Aircraft was received by Ames Research Center in the Fall of 1972. The jointly funded and managed NASA/Army program would be accomplished by an Aircraft Contractor selected by a Source Evaluation Board. The use of a formal Cost/Performance Management System was not envisioned at project initiation but evolved as a result of the winning Contractor's proposal. This paper briefly presents the fundamentals of the Cost/Performance System used, the Contractor's reporting system, the Government Project Office's analyses, and the use of this type of reporting system and recommendations concerning the use of like systems on future projects.

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