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This report provides an overview of the ATEC cost/benefit analyses conducted by the government and industry and some of the automation work accomplished by commercial telephone companies. It consolidates the results of many of the plans and studies pertaining to the ATEC cost/benefit analyses and provides an insight into the scope and depth of what has been accomplished. As a basis for comparison, information on some of the automation work accomplished by GTE and

20. (Abstract)

the Bell System including the indications and evidence of the cost/benefits they experienced is provided in the report. Recommendations are made for the conduct of future cost/benefit analyses for the ATEC program.

TN 7-78

DEFENSE COMMUNICATIONS ENGINEERING CENTER

TECHNICAL NOTE NO. 7-78

AN OVERVIEW OF THE COST/BENEFIT ANALYSES FOR THE AUTOMATED TECHNICAL CONTROL (ATEC)

NOVEMBER 1978

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FOREWORD

The Defense Communications Engineering Center (DCEC) Technical Notes (TN's) are published to inform interested members of the defense community regarding technical activities of the Center, completed and in progress. They are intended to stimulate thinking and encourage information exchange; but they do not represent an approved position or policy of DCEC, and should not used as authoritative guidance for related planning and/or further action.

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SUMMARY

A cost/benefit analysis requirement for the Automatic Technical Control (ATEC) system was established by the Office of the Secretary of Defense as early as mid 1974. Since that time a number of test plans addressing this analysis were prepared and implemented in various degrees. In addition, a number of studies were conducted and reports prepared that assessed the potential benefits of the ATEC and other automated systems.

This Technical Note (TN) documents the results of a DCEC effort to consolidate the many completed and ongoing tests, studies, and plans pertaining to the ATEC cost/benefit analysis. As a basis for comparison, information on some of the automated systems implemented and analyses conducted by commercial communications companies is included.

This TN provides an overview of the ATEC cost/benefit analyses and some of the automation work accomplished by GTE and the Bell system. It includes the following:

- A brief description of the various plans, and comments on their status, application, and results.
- An examination of the various studies for the purpose of determining their individual and composite contribution to the ATEC cost/benefit analysis.
- An examination of the test and analysis information available from the Air Force Joint Initial Operational Test & Evaluation (JIOT&E).
- An examination of some of the automation applications and analyses accomplished by the commercial companies.
- Some general conclusions pertaining to the ATEC cost/benefit analysis work accomplished to date and the requirements for the future.

It is recognized that no one particular study nor the composite results provide the basis for determining an absolute quantified measure of ATEC benefits. However, the variety of approaches taken in performing the studies and analyses delineated herein, and the general consensus of the benefits derived from ATEC and automation, do provide a high degree of confidence in the validity of the findings. The true value of this

TN lies in its application as a reference for future analyses. Use of the results of the various studies could eliminate duplication of effort and provide savings in time, manpower, and money. Applications anticipated are for the ATEC Follow-On Management Applications and Evaluation (FOMAE) and the Joint Initial Operational Test & Evaluation (JIOT&E) Phase II.

I. INTRODUCTION

1. PURPOSE

This TN documents the results of a DCEC effort to consolidate the many completed and ongoing tests, studies, and plans pertaining to the Automated Technical Control (ATEC) cost/benefit analysis. It provides an overview of what has been accomplished, the approaches and data bases for the analyses, the scope of the analyses, the currently available results and conclusions, and the adequacy relating to the total analysis effort. It also provides numerical and tabular results which can be used to project the relative cost of ownership and direct and indirect benefits which will be derived by a widespread deployment of ATEC production equipment in 1982-85. Several government test plans were addressed in this TN. They were included to show the depth of the ATEC cost/benefit analysis and the basic causes for changes in the test approaches and objectives. As a basis for comparison, information on some of the automation work accomplished by General Telephone and Electronics (GTE) and the Bell Telephone System is included.

2. BACKGROUND

The following is an overview of major events that occurred in the ATEC program. They are presented here to acquaint the reader with the initial ATEC program, the program redirection, and the change of system test and analysis requirements.

- Originally the program was a DCA sponsored, Air Force managed RDT&E effort to develop computer-assisted equipments for DCS Technical Control Facilities.

- Although the program was initiated as an RDT&E project, it was intended that procurement would follow the successful test and evaluation of the equipments.

- A contract was awarded to Honeywell Corp. (Nov '71) for accelerated development and test of 4 Stand Alone Equipments (SAE) and 1 Nucleus Subsystem (NSS). The SAE's were individual station test equipments and the NSS was a system oriented test and interface unit. These equipments were tested at Croughton and Hillingdon (1973) and were considered acceptable.

- A contract was awarded (Feb '74) to Computer Sciences Corp. for system performance assessment and operational algorithm formulation in support of ATEC. The resulting software was employed in the combined testing in Europe by means of a Sector/Nodal Simulator.

- A limited pilot production procurement of SAEs was authorized and contract was awarded Jan '75. This was intended to provide an improved configuration for test of the system oriented Nucleus Subsystem. During this period disc memory was added to the SAE to facilitate automatic reporting. This also provided additional capabilities to the In-Service Quality Control Subsystem (IQCS), In/Out Service Quality Control Subsystem (I/OQCS), and Digital Distortion Monitoring Subsystem (DDMS). These multifunction SAE's became known as the Programmable ATEC Terminal Elements (PATES).

- DTACC's Memorandum For Director DCA, DCS Technical Control Improvement Program (TCIP), 6 Aug 76 provided updated guidance on the ATEC portion of the TCIP. The memo noted that significant improvements in micro-processors and mini-computers could be used to the programs advantage. It further noted that continuing with the existing ATEC concept would result in the fielding of a manpower intensive system. Thus it was necessary to reorient the entire ATEC program. Effectively, the reorientation changed the procurement specifications from design to functional performance specifications; shifted the emphasis of the test program from individual equipment characteristics to system functional characteristics; specified a competitive procurement to fully exploit capabilities of the communications computer industry; and directed a Low Rate Initial Procurement (LRIP) so that an Initial Operational Capability (IOC) could be achieved prior to committing the Government to full scale ATEC procurement.

3. SOURCE DOCUMENTS

The following provides a list of documents pertaining to the ATEC cost/benefit analysis:

- The DCA Test Management Plan (TMP) (April 1975).

- AFTEC draft cost/benefit analysis for the ATEC program (25 May '76).

- AFTEC's Test Plan (JIOT&E) Phase I (Feb '77).

- DCA's MEP for the DCS Technical Control Improvement Program (Automated), dated Mar '77.

- Honeywell Inc., Systems and Research Center, ATEC cost-effectiveness analysis (7 Mar '77).

- DCEC Technical Report, TR 3-77, "O&M Manning" (Apr '77).

- Booz-Allen study report titled "Future DCS Cost Reduction Design Factor Study," dated 28 Feb '78.

- GTE Sylvania study titled "Digital Network Control Cost Benefits Study," dated 27 Oct '77.

- Air Force Communications Service, Automated Technical Control (ATEC), Benefits Analysis, June '78.

4. SCOPE

This TN provides an overview of the ATEC cost/benefit analyses and some of the automation work accomplished by GTE and the Bell System. It includes a condensed version of the various plans and analyses; a consolidation of the currently available analyses results; an evaluation of the value, contribution, and a qualitative assessment of each, the relation and application of the currently available results to the various cost/benefit elements, a brief description of some automated operational support systems employed by the telephone companies; indications of the magnitude of the cost/benefit derived from automation by the telephone companies, and, finally, some inferences that can be drawn for the DCS pertaining to the potential benefits resulting from Technical Control automation.

5. ORGANIZATION

Section II provides a brief description of the various analyses, plans, and reports; comments on their status, application, results, value, and contribution; and provides other observations as appropriate. Section III examines the various studies for the purpose of determining their individual and composite contribution to the overall cost/benefit analysis objectives. In addition, the test and analysis information available from the JIOT&E is examined. Section IV examines some of the automation work and applications accomplished by the commercial communications companies and the benefits derived or anticipated as a result of implementing these systems. Section V provides significant findings and conclusions.

II. PLANS AND STUDIES

1. DCA, TEST MANAGEMENT PLAN (TMP) FOR AUTOMATED TECHNICAL CONTROL (ATEC) SYSTEMS OPERATIONAL TEST. (ANNEX A, SECTION 7 - TEST AND EVALUATION MANAGEMENT ENGINEERING PLAN (MEP) FOR DCS TECHNICAL CONTROL IMPROVEMENT PROGRAM (TCIP)), APR '75

a. Description. This Plan addresses a three-phase ATEC program with implementation of the third phase dependent upon successful completion of the first and second phases. The phases are as follows:

Phase I. Developing and testing the ATEC Test Elements (ATE's) and Nucleus Subsystem (NSS) - AF Contract F30602-72-C-008 (Honeywell).

Phase II. Deploying these equipments to Europe and conducting the Development Test and Evaluation (DT&E) and limited Joint Operational Test and Evaluation (JOT&E) (Thin line test) - providing cost data to support FY 78 procurement.

Phase III. Conducting the ATEC System JOT&E.

The TMP specified two separate test plans consisting of:

- DT&E Plan. The primary objective of the DT&E relates to the analysis of the acquisition and the presentation and usefulness of the ATEC generated information to the technical controller, NSS operator, and the higher management levels. Additional objectives of the DT&E relate to secondary performance and other standard design requirements such as reliability, maintainability, safety, etc.

- JOT&E Plan. The primary objective of the JOT&E was to provide a cost/benefit/effectiveness analysis of ATEC in the test environment. The specific items to be addressed were the logistic supportability, reliability, maintainability, availability, interoperability, compatibility, manpower and training. These elements will provide inputs into the cost of ownership (COO) and the operational suitability determinations which in turn provide the basis for the cost benefit analysis. In addition, the system performance and operational effectiveness elements are evaluated to establish the effectiveness of the ATEC system.

b. Observations. Because of subsequent major changes in the ATEC program, the detailed cost/benefit analysis was deferred. This TMP was superseded by a new DCA MEP (Mar '77) that reflects the change in direction of the ATEC program and specifically addresses the test requirements for the LRIP decision.

2. AFTEC, COST/BENEFIT ANALYSIS FOR THE AUTOMATED TECHNICAL CONTROL (ATEC) PROGRAM (25 MAY '76)

a. Description. This Draft Plan provided a recommended approach for completing the cost/benefit analysis requested by DTACCS. The proposed analysis was to be conducted in two parts:

- The first part specifically addressed the cost and benefits of the ATEC System deployed in Europe for the Initial Operational Test and Evaluation (IOT&E).

- The second part of the cost/benefit analysis was an extrapolation to the proposed ATEC System configuration.

Each part was divided into two general areas:

- Cost of implementing ATEC.

- Benefits derived from ATEC in the operation and support of the DCS.

The approach for accomplishing the cost analysis was to compare the Cost of Ownership (COO) for the ATEC sites prior to and subsequent to the ATEC equipment installation. The cost elements were:

- Operation/Maintenance - (Personnel/Materials)

- Base Operating Support

- Logistic Support

- Personnel - (Training, Medical, Misc.)

- Recurring Investment.

The approach for accomplishing the Benefit Analysis was to compare the operations of the ATEC sites prior to and subsequent to the ATEC equipment installations. The benefit elements were:

- Reduction of operation and supply costs.

- Manpower - impact within and outside the test configuration.

- Manual Test equipments - reduction.
- Communications circuit availability.
- Communications circuit quality.

b. Observations. AFTEC'S recommended approach for completing the cost/benefit analysis for the ATEC program was neither finalized nor implemented. Discussions with AFTEC personnel revealed that the change in direction of the ATEC program made the approach obsolete and unworkable, and therefore dictated a new approach.

3. DCA, MANAGEMENT ENGINEERING PLAN FOR DCS TECHNICAL CONTROL IMPROVEMENT PROGRAM (AUTOMATED) (MAR '77)

a. Purpose. This Plan addresses the ATEC system and identifies it as an integral part of the Technical Control Improvement Program (TCIP). The order wire and manual upgrade portions of the TCIP are covered by separately published documents.

b. Description. Three types of test were addressed:

- Operational effectiveness of the ATEC System, including survivability, compatibility, and interoperability.
- Operational suitability (as required), including reliability, availability, maintainability, logistic supportability, operating and support cost, and training requirements.
- Operational Management Evaluation to determine changes and refinement of current DCA and O&M methods and procedures.

Tests were specified to be conducted in two major phases:

- Phase I, combined DT&E/JIOT&E, had the objectives to assess the operational effectiveness and those aspects of operational suitability derived from functional testing. The results will be used to refine operational concepts, procedures, applications, and ATEC performance specifications, and to provide information to the LRIP procurement decision.
- The Phase II test will be conducted on the initial operational capability (IOC) configuration of the LRIP ATEC equipment that represents the system to be fielded for the final operational capability (FOC) post FY 82-83. The objectives of this test are to assess the operational effectiveness of the production equipment, validate conclusions and projections of the Phase I test, and support the large scale procurement decision for the FOC equipments.

c. Observations. This plan served the purpose of integrating the ATEC program with the TCIP and providing the basic objectives of the JIOT&E Phase I Test. Further, it established the requirement for and the basic objectives of the Phase II JIOT&E Test and the guidelines for the preparation of the test plan.

4. AFTEC, TEST PLAN, JOINT INITIAL OPERATIONAL TEST AND EVALUATION (JIOT&E) PHASE I, AUTOMATED TECHNICAL CONTROL (ATEC) (FEB '77)

a. Background. This plan superseded the initial AFTEC Test Plan dated Oct '75. The initial plan was used for the first effort test period (Oct '75 - Mar '77) using production prototype ATEC equipments installed in six sites in Germany. This effort was devoted to training the Test Force, developing operational procedures, establishing DCS performance/manpower baseline supporting DT&E and accomplishing certain limited JIOT&E objectives.

b. Description. The JIOT&E Phase I Test Plan was dictated by:

- Redirection of the ATEC program, which required restructuring of the JIOT&E plan.

- The requirement for the evaluation of the manpower and operational effectiveness, directed by DTACC's to be conducted to committing the DoD to an ATEC LRIP.

This new plan was used for the second effort test period (Apr '77 - Feb '78) using initial production equipments installed in nine sites located in Germany, Italy and the United States. This effort was devoted to evaluating the operational effectiveness of, and the impact on, operational manpower of the ATEC system in the operational environment. The plan addressed the JIOT&E Phase I effort to provide inputs for the DTACC's LRIP decision. Additional JIOT&E (Phase II) necessary to provide inputs for the full-scale production decision in FY 81 will be addressed in a separate test plan document. Phase II testing will be conducted on a representative test configuration of LRIP assets. As opposed to Phase I, this phase will assess the full range of test objectives necessary to support production decisions. The rationale for the limited cost/benefit analysis specified in the Phase I test plan is:

- Manpower requirements related to maintenance of the currently deployed ATEC equipments are not representative of those for the proposed LRIP equipments.

- The logistic support aspects of the current deployed ATEC equipments are not representative of those for the proposed LRIP equipments.

c. Observation. The data collected during the second effort test period and in part from the first effort test period reflects the operational effectiveness of the initial production equipments. It further shows the impact on the operational manpower requirements of the test sites. This data is the basis for the Test Report prepared by AFTEC dated Aug '78.

5. HONEYWELL INC., ATEC COST-EFFECTIVENESS ANALYSIS (7 MAR '77)

a. Description. This analysis was a Honeywell Systems and Research Center in-house effort at no cost to the government. The objective was to determine the costs and benefits of installing ATEC in the Defense Communications System. It was noted in the report that a rigorous cost-effectiveness analysis considering all of the life cycle costing aspects was not undertaken. The functions selected for analysis included:

- In-service circuit quality assurance
- Out-of-service circuit quality assurance
- Signal level discipline
- Route assessment
- Reporting
- Recordkeeping
- Fault isolation
- Restoral.

The ten major areas considered were:

- Technical control facility personnel
- Nodal and sector personnel
- Maintenance personnel
- Management and overhead
- Manual test equipments
- Test equipment support personnel
- Commercial rebates

- Training

- ATEC hardware and software support

- ATEC acquisition and installation.

A model for each of these areas was constructed in the form of a simplified representation of the real world, with abstract features relative to the question being studied. To facilitate the computations, a computer program was written to be run on the Tektronics 4051 Graphic Display System.

For each area, the cost of performing the function with and without ATEC was estimated. Calculations were based on the UK Sector of the 1982 DCS configuration. The cost difference between manual and ATEC operation for each factor was expanded to a worldwide cost by multiplying by a world/UK Sector ratio. Total annual net worldwide cost savings with ATEC were then calculated. A cost recovery indication was then calculated by dividing the total government budget for ATEC ($72 million) by the net annual cost savings.

The ATEC Cost-Effectiveness Analysis ground rules were:

- The cost analysis was based on 1982 DCS configuration which includes digital implementation (DEB).

- The cost of government personnel was based on 1975 dollars. Government will use existing assets to transport and install ATEC. No direct cost was assumed.

- All costs were yearly costs unless otherwise noted.

- The extension of UK ATEC costs to world ATEC costs assumed a sector/world ratio of 1/10. An exception was made for commercial rebates where a sector/world ratio of 1/3 was assumed.

- The cost of ATEC equipment and software was assumed to be a one-time charge equal to the Government ATEC total budget of $72 million.

b. Results. Table I summarizes the results. The first column labeled "FACTOR" lists the nine areas considered in the cost and savings analysis. Associated with each factor are the resulting costs without and with ATEC (columns 2 and 3). The difference is shown in column 4 with a "+" indicating a savings due to ATEC implementation and a "-" indicating an additional cost due to ATEC. These costs and savings are estimates for the UK sector only. Each is then factored by 10 or 3 (see ground rules) to arrive at the worldwide cost and savings. Finally, the total ATEC benefit of $19.4 million is divided into the cost of ATEC ($72 million) to obtain the time to the breakeven point of 3.7 years.

TABLE I. ANNUAL COST/BENEFIT ANALYSIS RESULTS

FACTOR	COSTS WITHOUT ATEC	COSTS WITH ATEC	UK SECTOR ATEC BENEFITS	WORLD ATEC BENEFITS
TCF Personnel	$2,410,000	$1,930,000	+ $480,000	+ $4,800,000
Node & Sector Personnel	-0-	139,000	- 139,000	- 1,390,000
Scheduled Maintenance Personnel	1,450,000	1,160,000	+ 290,000	+ 2,900,000
Mgt. & Over-head Personnel	418,000	286,000	+ 132,000	+ 1,320,000
Manual Test Equipment	70,000	10,000	+ 60,000	+ 600,000
Test Equip. Support Personnel	40,500	24,300	+ 16,200	+ 162,000
Commercial Rebates	960,000	4,800,000	+ 3,840,000	+ 11,500,000
Training	885,000	808,000	+ 77,000	+ 770,000
Hardware (HW) Software (SW) ATEC Support	-0-	131,000	- 131,000	- 1,310,000

TOTAL ANNUAL WORLD ATEC BENEFITS (1975 $'s): +$19,400,000

TOTAL GOVERNMENT ATEC BUDGET: $72,000,000

TIME TO BREAKEVEN POINT (1975 $'s): 3.7 years

TOTAL ANNUAL WORLD ATEC BENEFITS (1982 $'s): $26.0 Million

TIME TO BREAKEVEN POINT (1982 $'s): 2.8 years

c. Observations. This analysis presents evidence that there could be manpower savings by automating certain functions in the technical control area. It provides some useful information and analytical proof of monetary benefit that can be derived from ATEC utilization. However, the savings attributed to commercial rebates as a result of ATEC appears to be highly exaggerated. This appreciably reduces the dollar savings shown in the report.

6. DEFENSE COMMUNICATIONS ENGINEERING CENTER (DCEC) TECHNICAL REPORT NO. 3-77, O&M MANNING STUDIES (APRIL '77)

a. Description. This Technical Report comprises three studies pertaining to manning reductions. The one applicable to the ATEC cost/benefit analysis is "the Manning Reduction by Automation of the technical control functions." The objective of this study was to develop a family of curves showing the relationship between the desired performance level at technical controls, degree of automation provided, number of technical controllers needed, and the breakeven cost for automation.

The study was limited to the technical control operating personnel performing in a peacetime environment with analog (FDM) systems. No consideration was given to supervisory, maintenance, or support personnel. Data collected from 14 sites in the European area was used as a basis for the analytical computations.

Five major areas considered were:

- Quality Assurance-Testing (preventive maintenance)
- Circuit restoration and fault clearing
- Assistance to other facilities
- Logs and reports
- Standby times.

From an analysis of the operations, the technical control facility was assumed to be a multiserver queueing system. The model was designed to represent the operations noted above and to have specific characteristics pertaining to arrival patterns, service patterns, queue disciplines, system capacity, etc.

The overall methodology used in this study was to analyze current and optimal manning levels in technical control sites. The future manning levels were based upon the anticipated capabilities of automated technical control equipment. Relative comparisons were then made between the "before" and "after" optimal manning levels in order to determine the expected benefits from the automation.

Figure 1 shows the average number of technical controllers required to maintain an expected availability of circuits in the nonautomated model. The plotted values were derived from the following formula:

$$E(A) = \frac{N(ch) - E(ci)}{N(ch)}$$

where: E(A) = Expected availability of circuits
N(ch) = Number of circuits handled
E(ci) = Expected number of inoperative circuits in the queueing system.

Figure 2 presents a family of curves reflecting the effect of automation in the form of an increase in the technical controllers' service rate. This service rate applies to fault clearing, assistance to other facilities, and reporting. This graph can be used to predict the manpower savings that would result from an assumed percentage improvement, attributable to automation, in the service rates of the individual technical control functions.

Figure 3 shows, for two different values of desired circuit availability, the breakeven price that can be paid for automated equipment if this cost is to be offset by the manpower savings. The life-cycle cost was for a 10 year period and the manpower cost was based on the composite cost of $20,285 for a military man overseas.

Figure 4 provides a specific case of the manpower savings that could reasonably be expected through automation. Estimates of potential service rate improvements, neither optimistic nor pessimistic, were used in this graph.

b. Results. The analysis showed that automation of the technical control equipment improved the service rate of the technical controller and reduced the time required for fault clearing and reporting functions. The number of controllers required "before" and "after" automation was reduced from 7 to 5 per watch.

c. <u>Observations</u>. The conclusions presented in this study noted: the credibility of the findings needs to be more firmly established before they can be considered a proper base for a cost/benefit analysis; examination of several additional topics is required to ascertain the impact of automation on all elements of the technical control and support manning; and the analysis is useful in predicting the extent to which automation of technical control functions would prove to be cost-effective.

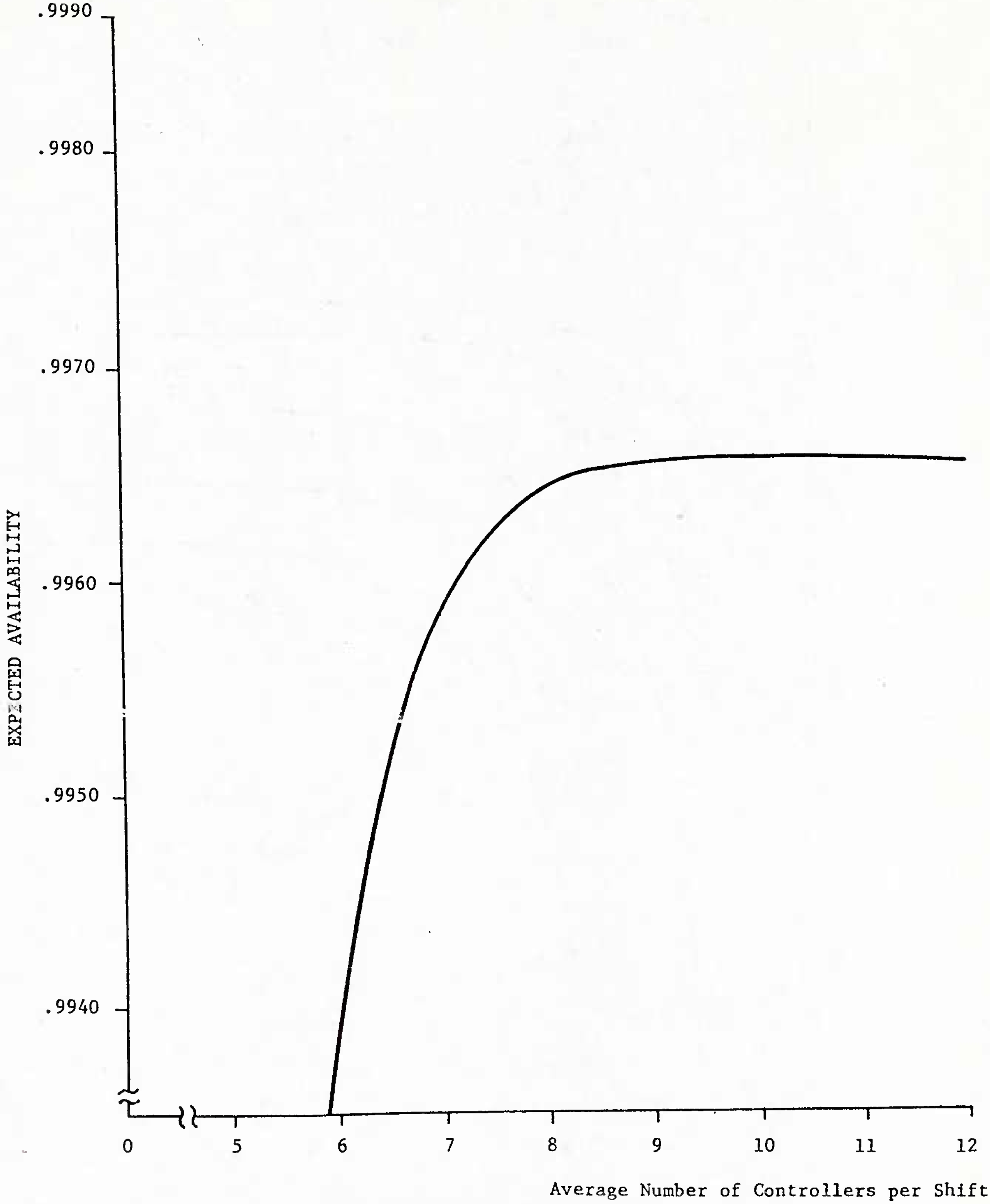

Figure 1. Availabiliy vs number of controllers; DCS site Croughton.

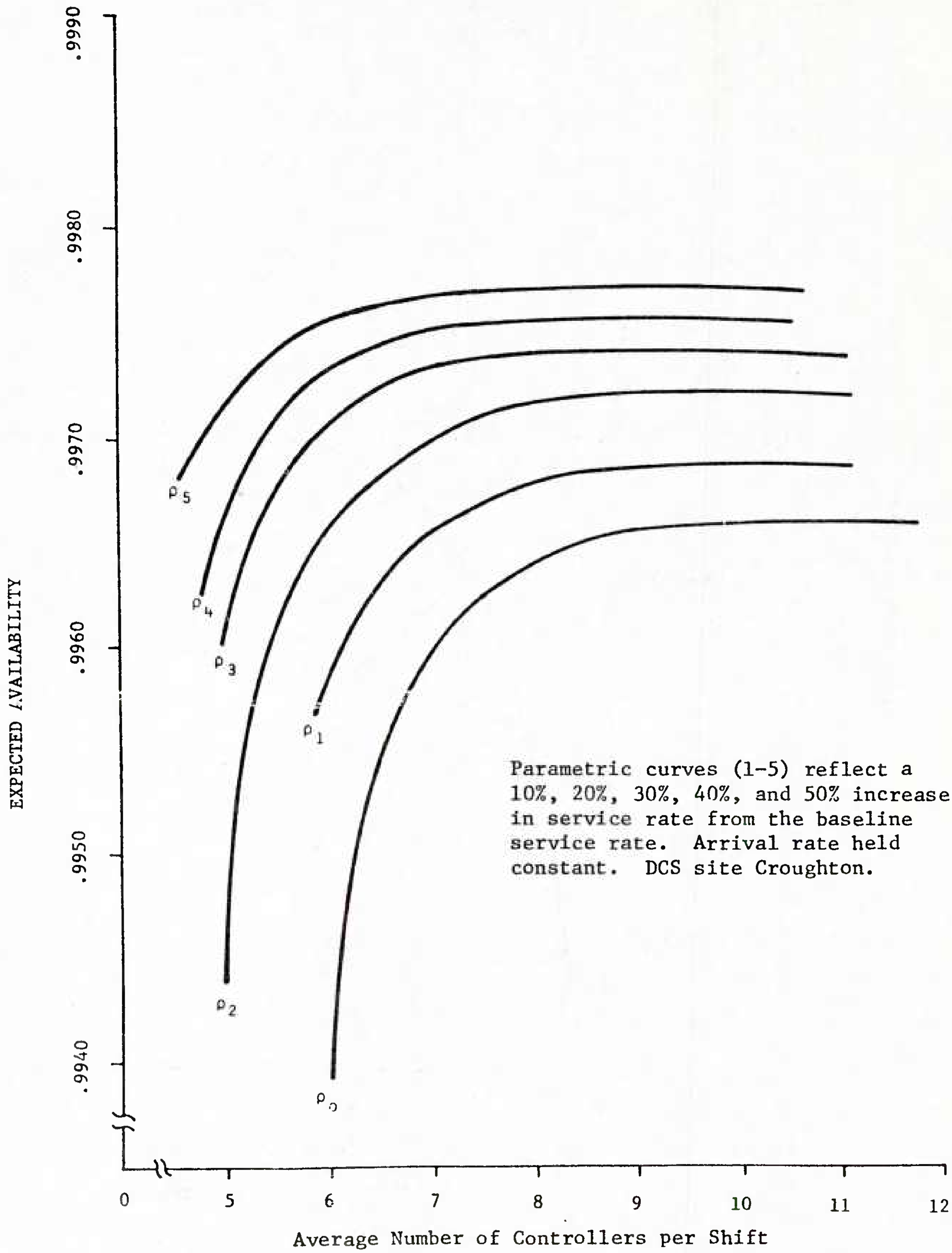

Figure 2. Potential effects of automation.

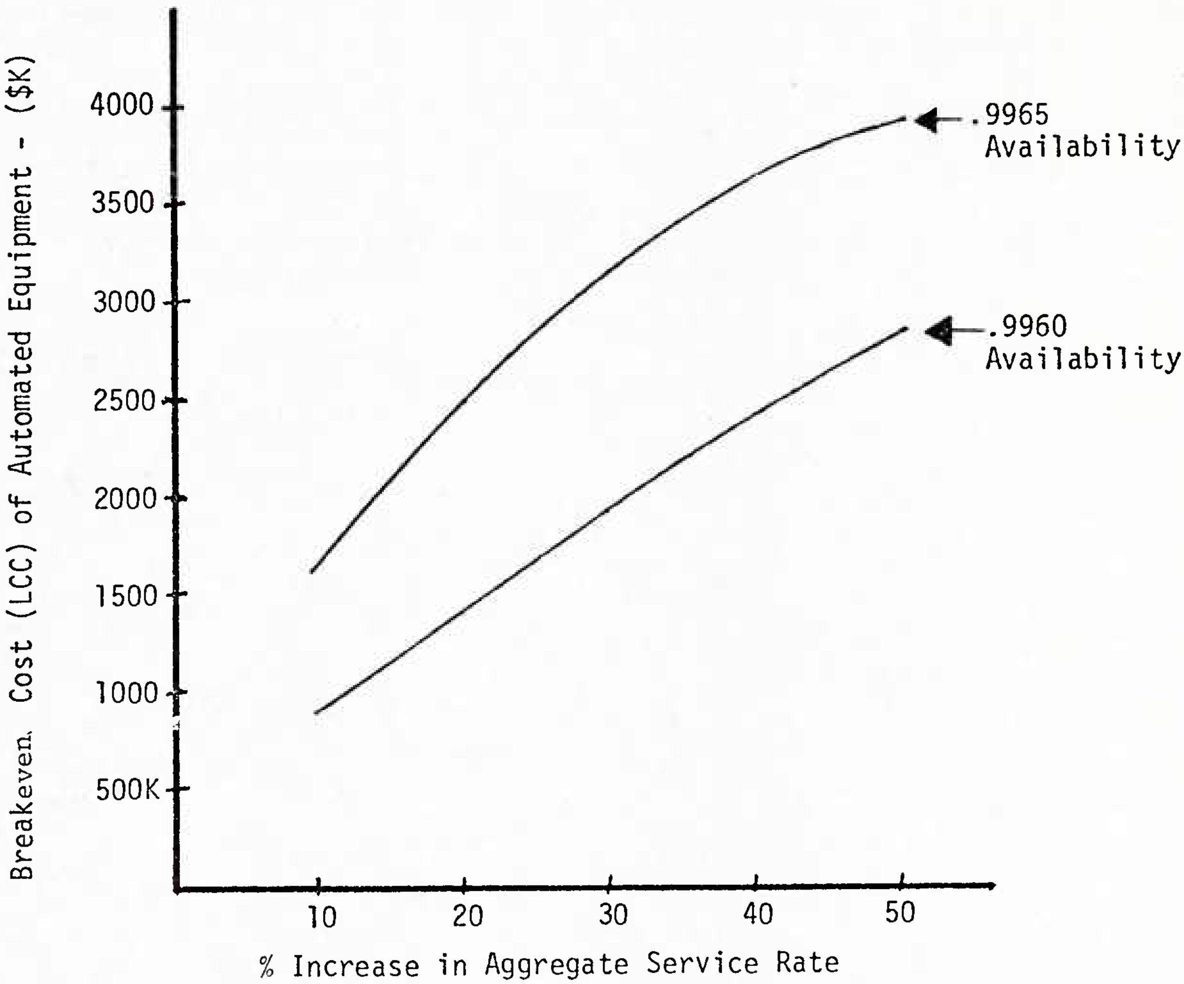

Figure 3. Breakeven Cost of Automated Equipment - DCS Site, Croughton

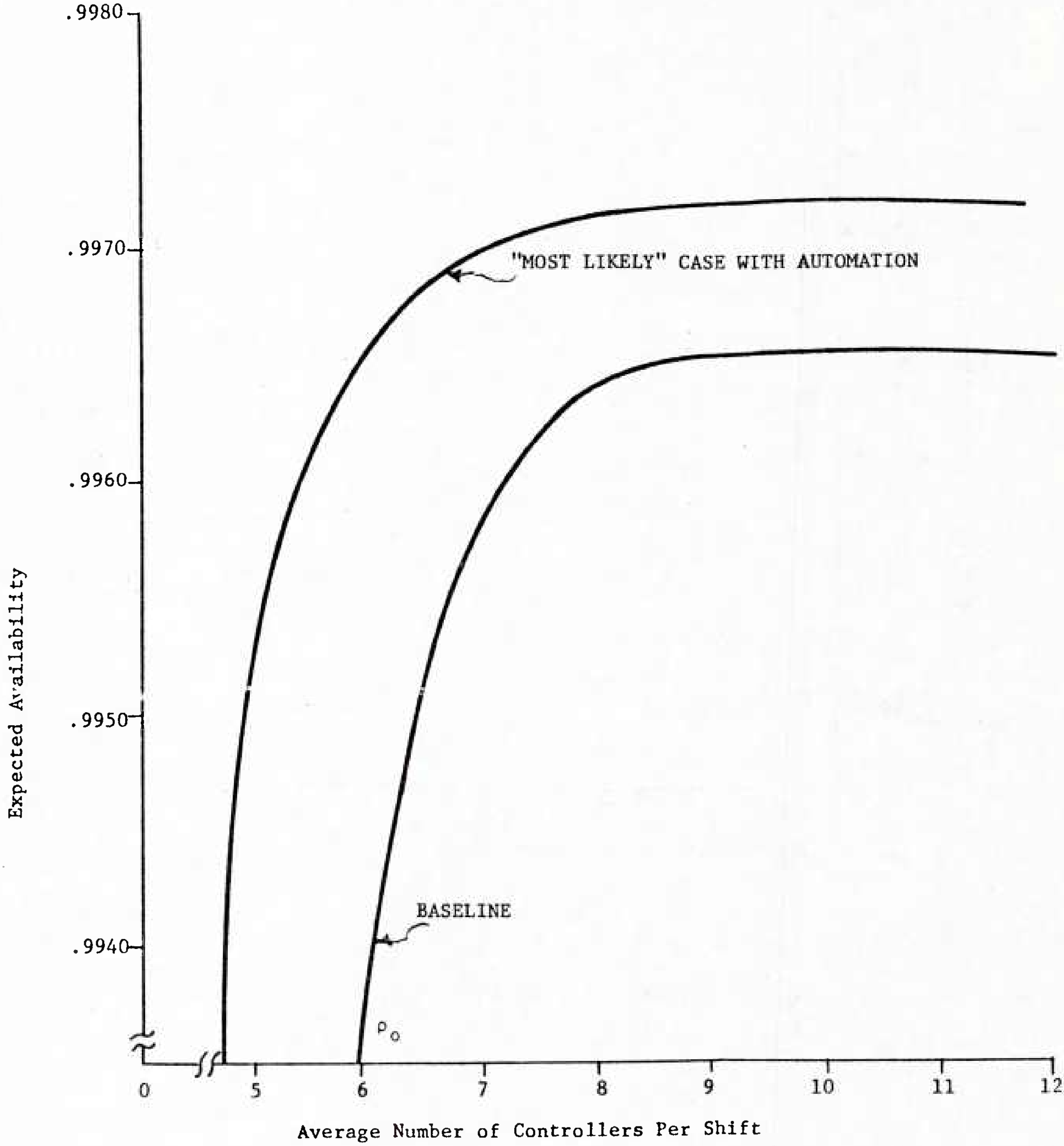

Figure 4. Comparison of "Before" and "After" Automation Availability vs Number of Controllers. DCS Site Croughton

7. BOOZ-ALLEN, "FUTURE DCS COST REDUCTION DESIGN FACTORS STUDY," FINAL REPORT (28 FEB '78)

a. Description. This study was conducted for DCEC under Contract No. DCA 100-77-C-0012 by Booz-Allen Applied Research. The final report was submitted on 28 Feb '78 and presents the analysis, results and conclusions of the study.

The objective of this study was to project the cost, O&M manning requirements, and operational effectiveness of station-level DCS technical control facilities (TCF) during the time period 1982-92. The study concentrated on examining the impact of automating tech control functions as the DCS Europe backbone transmission system evolves from analog to digital. In particular, the effects of varying the degree of TCF automation and of the evolution of the DCS-Europe backbone transmission system from analog to digital on cost, O&M manning requirements, and operational effectiveness were analyzed.

The study concentrated on O&M cost and manpower requirements associated with tech controls due to the following:

- Labor intensiveness of TCF's.
- Potential O&M cost reductions by deployment of ATEC.
- The impact of evolving from analog to digital transmission on the ATEC and its O&M cost.
- The importance to decisions concerning deployment of ATEC equipments in the future DCS.

The approach used for this study was to break it down to five specific tasks:

Task I - Develop a Subnetwork Model. The model consisted of three "snapshots" corresponding to specific points in time when a specified communications capability would be available in the European DCS. The "snapshots" (stages) are as follows:

- Stage I: European backbone transmission implemented through DEB IV - 50% analog, 50% Digital (approx. 1982).
- Stage II: Further digitization of backbone transmission - introduction of TTC-39, DAX, AUTODIN II (approx 1987).
- Stage III: Backbone virtually 100% digital - automatic channel reassignment introduced (approx 1992).

The Subnetwork Model consisted of 16 transmission sites of which 7 were selected for detailed analysis. The sites selected are those planned to employ ATEC LRIP equipments. The design was based on detailed data provided by DCA for Stage I and projected by Booz-Allen in this study for Stages II and III.

Task II - Develop Tech Control Alternatives. The tech control alternatives provided the basis for showing the impact of varying the degree of automation of tech control functions on cost, O&M manning requirements, and operational effectiveness for the three time frames. The tech control functions considered were:

- Fault Isolation
- Circuit Restoral
- Performance Monitoring Program (PMP)
- Quality Control (QC)
- Coordination
- Reporting.

The tech control alternatives were:

- Baseline ATEC: Full ATEC capabilities as specified in the ATEC System Specification No. ATEC 10000, June '77 (Draft), and additional capabilities for digital equipments, as specified in RADC-TR-76-302, "ATEC Digital Adaptation Study - FKV reqmts for PA/FI/TA," Honeywell, Inc., Oct '76 (Final Report).
- Limited ATEC: Based on reduction of ATEC equipment elements; eliminated the automation of PMP/QC test and the trending analysis for dc circuits.
- Enhanced Fault Alarm and Status Reporting (EFASR): Provides for modest upgrade of the present FASR equipment alarm and reporting system used in the FKV test bed. QC testing and analysis for analog circuits and FDM equipments are manual.

TASK III - Develop Analysis Procedure. The primary emphasis was to quantify O&M manning requirements, cost, and operational effectiveness for the three technical control alternatives during each of the "snapshot" stages. The technique developed was based on the queueing theory and the earlier work performed by DCEC (TR 3-77, "O&M Manning Study," Apr '77).

A second technique was developed based on "accepted" DoD procedure (ORT-032-74-V2, "Cost effectiveness plan for Joint Tactical Communications," JTCO, Vol II, Nov '74 and B.J. Hansen, "Practical PERT," American House, Washington, D.C., Nov '64). This was used to verify and calibrate the Queueing-Theoretic Model.

Task IV - Collect Data. The main data items included: Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), report/alarm characteristics of the transmission and tech control equipment, and the average times required to perform various tech control functions including recommended individual QC/PMP test.

Task V - Analyze Alternatives. The objective was to determine the operations manning requirements, operational effectiveness, maintenance manning requirements, and cost for the three tech control alternatives for each time stage and for each of the seven sites selected for detailed analysis.

b. Data Developed. Tables II through XIII provide the computational results of the analysis. The results shown in Tables II through IX were based on the cost methodology that assumed a rate of digitization of DCS Europe corresponding to Stages I through III described under Task I above. Tables X through XIII reflect an increased rate of digitization and percentage of unmanned sites. The alternative rates compared against the baseline (7 site configuration) were:

- Rate A - The transmission subnetwork for the 10-year time frame initially corresponds to Stage II with a gradual transition to Stage III by the fifth year.

- Rate B - The subnetwork corresponds to Stage III for the entire 10-year time frame.

Table II presents the total operations manning requirement for the six manned sites of Camadoli, Coltano, Hohenstadt, Mt. Corna, Stuttgart, and Zugspitze. The unmanned site at Friolzheim is not included in this computation. Note that the baseline ATEC has the lowest manning requirements in all three stages. Automation of the technical control functions, particularly in the areas of reporting, circuit testing, and fault isolation, accounts for this low manning requirement.

Table III presents the results of the maintenance manning analysis in terms of total maintenance hours per month for the seven sites noted above. It can be seen that the total maintenance requirements for transmission equipments decrease by about 35% between Stages I and III. This decrease is due to the replacement of analog equipment by more reliable digital equipment and reduction of first-level multiplexers by introduction of digital network control (DNC) equipments during Stage III. Also of interest is that the maintenance requirement of the EFASR alternative averages about 17% of that of the ATEC alternatives because of the higher reliability. However, the overall maintenance hours are so low that this does not significantly increase total maintenance requirement for manned sites. Table IV presents a summary of Tables II and III, and shows the manning and circuit availability criteria used in the manpower computation.

Table V presents the total Mobile Maintenance Team requirements for three unattended sites during the Stage I period. This includes travel time to and from the home base, Mt. Corna, for servicing the unattended sites at Mt. Serra, Mt. Cimone, and Paganella. It can be seen that both ATEC alternative equipments significantly contribute to the composite maintenance requirement. It was estimated that a team would visit an unattended site equipped with EFASR once every 33 days and would visit ATEC once every 19 days. This difference is due primarily to the lower reliability of ATEC compared to EFASR.

Tables VI and VII broke down the initial non-recurring equipment-related cost items and the recurring cost items over a 10 year period for the seven sites noted above. Table VIII combined these tables to present a cumulative 10 year cost summary. The purpose of these tables was to compare equipment and operations manning cost of the three alternative systems to determine what degree of automation is economically advantageous.

Table IX presents equipment and operations manning cost for selected sites representative of the type of stations in DCS Europe. It can be seen that the significant cost advantage to the ATEC is attributable primarily to the terminals and large branched repeaters. This result was expected since these sites have responsibility for circuit testing which is highly automated in the ATEC alternatives and manual in the EFASR alternative.

Table X presents the equipment and operations manning cost cumulated for a 10 year period for the varying digitization rates. The costs are for all seven sites and are given for all three technical control alternatives. It can readily be seen that the 10 year cost differences between the alternatives diminish with increasing digitization. The EFASR costs are only 19% and 8% higher than baseline ATEC for digitization rates A and B, respectively. This is considerably lower than the differences at the baseline digitization rate in which the EFASR cost are 31% higher than baseline ATEC. This discrepancy is due primarily to the very low need for automated circuit and link testing in the digital environment.

Table XI compares equipment and operations manning cost for the baseline subnetwork model with the unmanned subnetwork variation. The unmanning of the three repeater sites resulted in a cost reduction of $4.4 million and $6.7 million (approximately 30%) for the ATEC and EFASR, respectively. The analysis indicated that additional unmanning of sites did not appreciably change the cost differences between the alternatives.

Table XII presents the results of categorizing the 132 DCS sites in the U.K., Germany and Italy in those categories previously indentified. Table XIII presents the equipment-related and operational manning-related, cumulative 10 year costs for these sites for varying digitization rates. The costs were calculated using the cost developed in the preceding analysis and weighted by the frequency of occurrence of the particular category. The "Stage I only" digitization rate corresponds to no increase of digitization after Stage I and was included to show the affect of digitization alone on total cost. The costs for the projected DCS, as in previous calculations, show that the baseline and limited ATEC have lower total cost than EFASR when the digitization rate corresponds to the baseline or lower. At higher digitization rates A and B, total costs of all three alternatives, are within 2% of each other.

TABLE II. OPERATIONAL MANNING REQUIREMENTS
(7-SITE TOTALS)

Alternative	Manning Category	Stage I	Stage II	Stage III
Baseline ATEC	M/S	19.8	18.3	9.8
	M/S + M/D	20.1	18.7	10.2
Limited ATEC	M/S	22.3	20.8	10.2
	M/S + M/D	23.1	21.2	11.0
EFASR	M/S	26.1	27.2	12.9
	M/S + M/D	29.2	31.5	14.1

M/S = Manning level for stochastic events.

M/D = Manning level for deterministic events.

Notes: (1) Manning levels in man-hours per operating hour (MH/OH).
(2) One site is unmanned.

TABLE III. MAINTENANCE MANNING REQUIREMENTS
(7-SITE TOTALS)

Equipment Type	MMH/Month		
	Stage I	Stage II	Stage III
Transmission	41.2	28.4	14.3
Tech Control			
Baseline ATEC	5.7	6.5	4.8
Limited ATEC	4.2	4.4	4.8
EFASR	0.8	0.8	0.8
DNC	-	-	4.2
Composite*			
Baseline ATEC	46.9	34.9	23.3
Limited ATEC	45.4	32.8	23.3
EFASR	42.0	29.2	19.3

NOTES: (1) Maintenance man-hours per months (MMH/month).
(2) *MMH/Month for Transmission and Tech Control and DNC.

TABLE IV. SUMMARY OF RESULTS - OPERATIONAL AND MAINTENANCE MANNING

	Alternative		
	Baseline ATEC	Limited ATEC	EFASR
Operations Manning (1) (man-hours/operating hour)			
Stage I	20.1	23.1	29.2
Stage II	18.7	21.2	31.5
Stage III	10.2	11.0	14.1
Operational Effectiveness (2)			
Manning Availability	0.998	0.998	0.998
Circuit Availability	0.99989	0.99979	0.99980
Priority Circuit Availability	>0.9999	>0.9999	>0.9999
Maintenance Manning (1,3) (man-hours/operating hour)			
Stage I	0.065	0.063	0.058
Stage II	0.049	0.046	0.041
Stage III	0.032	0.032	0.027

Notes:
(1) Total for seven sites.
(2) Averaged across time stages and six sites; Friolzheim not included since unmanned.
(3) Include transmission, tech control, and DNC maintenance.

TABLE V. MOBILE MAINTENANCE TEAM REQUIREMENTS (STAGE I)

	3-Site Total Requirements (MMH/Month)		
	Baseline ATEC	Limited ATEC	EFASR
Transmission	16.2	16.2	16.2
Tech Control	11.7	9.9	2.4
Composite	27.9	26.1	18.6

NOTE: (1) Maintenance man-hours per month (MMH/month).

TABLE VI. NON-RECURRING EQUIPMENT-RELATED COST ITEMS (7-SITE TOTALS)

Cost Item	Baseline ATEC ($K)	Limited ATEC ($K)	EFASR ($K)
	Alternatives		
Research & Development (R&D) (1)	205	139	37
Procurement			
• Prime Mission Equip (PME)	620	420	102
• Installation	620	420	102
• Integration & Assembly	124	84	20
• Training	62	42	10
• Test & Evaluation (2)	62	42	10
• Program Management	78	53	13
• Initial Spares	93	63	15
• Transportation	31	21	5
• Data	124	84	21
• Inventory Administration	124	84	21
Total	2,143	1,452	356

NOTES: (1) Includes software.
(2) Includes test equipment.
(3) All cost figures in 1977 constant dollars.

TABLE VII. RECURRING COST ITEMS (7-SITE, 10-YEAR TOTALS)

Cost Item	Alternative: Baseline ATEC ($K)	Alternative: Limited ATEC ($K)	Alternative: EFASR ($K)
Equipment-Related			
• Maintenance Manning	124	84	11
• Spare Parts & Modules	186	126	26
• Inventory Administration	717	533	140
• Other O&M	319	228	49
Operations Manning	13,893	15,750	22,228

NOTE: (1) All cost figures in constant 1977 dollars.

TABLE VIII. COST SUMMARY (10-YEAR CUMULATIVE)

(a) 7-Site Total Cost

	Baseline ATEC ($M)	Limited ATEC ($M)	EFASR ($M)
Equipment (1)	3.49	2.57	0.59
Operation Manning	13.89	15.75	22.23
Total	17.38	18.32	22.82

(b) Terminal Total Costs (4 Sites)

	Baseline ATEC ($M)	Limited ATEC ($M)	EFASR ($M)
Equipment (1)	2.69	1.85	0.34
Operations Manning	11.54	13.34	18.70
Total	14.23	15.19	19.04

(c) Repeater Total Costs (3 Sites)

	Baseline ATEC ($M)	Limited ATEC ($M)	EFASR ($M)
Equipment (1)	0.80	0.72	0.25
Operations Manning	2.35	2.41	3.53
Total	3.15	3.13	3.78

NOTES: (1) Includes non-recurring and recurring costs; see Tables VI and VII.
(2) All cost figures in constant 1977 dollars.

TABLE IX. COST SUMMARY-REPRESENTATIVE SITE TYPES (10-YEAR CUMULATIVE)

			Tech Control Alternative		
Type of Site	Site	Category	Baseline ATEC ($M)	Limited ATEC ($M)	EFASR ($M)
Large Terminal	Stuttgart	Equipment	.70	.48	.16
		Operations Manning	3.18	3.74	5.42
		Total	3.88	4.22	5.58
Intermediate/ Small	Mt. Corna	Equipment	.68	.47	.06
		Operations Manning	2.04	2.15	3.14
		Total	2.72	2.62	3.20
Branched Repeater	Camadoli	Equipment	.36	.33	.05
		Operations Manning	1.53	1.59	2.76
		Total	1.89	1.92	2.81
2-Way Repeater (Manned)	Zugspitze	Equipment	.29	.20	.05
		Operations Manning	.82	.82	.82
		Total	1.11	1.02	.87
2-Way Repeater (Unmanned)	Friolzheim	Equipment	.11	.11	.04
		Operations Manning	0	0	0
		Total	.11	.11	.04

NOTES: (1) Includes non-recurring and recurring costs.
(2) All cost figures in constant 1977 dollars.

TABLE X. TOTAL 10-YEAR COST FOR VARYING DIGITIZATION RATES (7-SITE TOTALS)

Digitization Rate	Cost	Tech Control Alternative: ATEC ($M)	Limited ATEC ($M)	EFASR ($M)
Baseline (Table VIII(a))	Equipment (1)	3.49	2.57	.59
	Operations Manning	13.89	15.75	22.23
	Total	17.38	18.32	22.82
A	Equipment (1)	3.42	2.23	.58
	Operations Manning	9.81	11.15	15.18
	Total	13.23	13.38	15.76
B	Equipment (1)	2.88	2.00	.58
	Operations Manning	8.39	9.05	11.60
	Total	11.27	11.05	12.18

NOTES: (1) Recurring and non-recurring cost.
(2) All cost figures in constant 1977 dollars.
(3) Rate A - the transmission subnetwork for the 10 year time frame initially corresponds to Stage II with gradual transition to Stage III by the fifth year.
(4) Rate B - the subnetwork corresponds to Stage III for the entire 10 year time frame.

TABLE XI. TOTAL 10-YEAR COST FOR INCREASED NUMBER OF UNMANNED SITES (7-SITE TOTALS)

Manning Assumptions	Cost	Tech Cntl Alternative: ATEC ($M)	Limited ATEC ($M)	EFASR ($M)
Baseline (Table VIII(a))	Equipment (1)	3.49	2.57	.59
	Operations Manning	13.89	15.75	22.23
	Total	17.38	18.32	22.82
Mt. Corna, Zugspitze and Camadoli Unmanned	Equipment (1)	3.17	2.25	.59
	Operations Manning	9.51	11.19	15.50
	Total	12.68	13.44	16.09

NOTES: (1) Recurring and non-recurring cost.
(2) All cost figures in constant 1977 dollars.

TABLE XII. CATEGORIZATION OF 132 DCS SITES IN EUROPE

Site Category	Number of Sites	% Representation
Large Terminal (Stuttgart)	11	8
Terminal/Small (Mt. Corna)	84	64
Branched Repeater (Camadoli)	9	7
2-Way Repeater, Unmanned (Friolzheim)	28	21
Total	132	100

TABLE XIII. TOTAL COST FOR PROJECTED DCS - EUROPE (10-YEAR CUMULATIVE, 132 SITES)

Digitization Rate	Cost Categories	Degree of Automation: ATEC ($M)	LIMITED ATEC ($M)	EFASR ($M)
Stage I only	Equipment-related	70.26	50.70	8.37
	Operations Manning	253.11	281.15	415.37
	Total	323.37	331.85	423.74
Baseline (Table XII)	Equipment-related	70.26	50.81	8.37
	Operations Manning	220.99	248.69	348.22
	Total	291.25	299.50	356.59
A	Equipment-related	70.26	38.35	8.37
	Operations Manning	190.30	222.53	248.19
	Total	263.56	260.88	256.56
B	Equipment-related	48.34	36.19	8.37
	Operations Manning	180.29	183.87	215.28
	Total	228.63	220.06	223.65

NOTES:
(1) Recurring and non-recurring cost.
(2) All cost figures in 1977 dollars.
(3) Rate A - the transmission subnetwork for the 10 year time frame initially corresponds to Stage II with gradual transition to Stage III by the fifth year.
(4) Rate B - the subnetwork corresponds to Stage III for the entire 10 year time frame.

c. Results. The significant results of this study are:

- Operations manning requirements for Baseline ATEC are significantly lower than the other two alternatives for all three time stages.

- Operations manning of all alternatives drops (factor of 2) as the backbone transmission plant evolves from 50% digital (Stage I) to nearly 100% digital (Stage III).

- At attended sites, the maintenance manning requirements are less than 1% of the operations manning requirements for all alternatives and all time stages.

- Due to mobile maintenance team travel time, the low specified MTBF of ATEC equipment substantially increases maintenance requirements at unattended sites relative to the EFASR equipment.

- The large and substantial operations manning cost advantage of the baseline ATEC more than compensated for the expense of the equipment.

- The 10 year cumulative total cost for each alternative (equipment-related plus operations manning) is a major function of the rate of conversion to digital DCS.

d. Conclusions. The following conclusions were developed by Booz-Allen:

- The baseline ATEC alternative is preferred over the other two alternatives.

- It is cost effective to maximally automate station level tech control functions.

- Full digitization of the DCS backbone transmission facilities can be expected to reduce the number of tech controllers required to perform the functions studied.

- System-wide implementation of baseline ATEC could significantly reduce operations manning requirements and result in substantial annual cost savings, despite higher maintenance and acquisition costs, compared to a minimally automated EFASR system.

- The total comulative costs and operations manning requirements for all three alternatives are strongly dependent on both the length of time over which the transmission subsystem evolves to an all-digital network, and the percentage of unmanned sites. Total maintenance requirements are small for all alternatives and are not significant evaluation factors.

- Based on extrapolation of the results of this study to 132 DCS sites in Europe, the Baseline ATEC is the preferred alternative when the length of time to transition to an all-digital system equals or exceeds 10 years.

- When the digitization transition period is less than 7 years, the EFASR alternative has a total cost very close (within 2%) to the ATEC alternatives. The EFASR could become cost competitive by automation of its coordination and reporting functions, in combination with a rapid evolution to a DCS digital transmission subsystem. However, the operation manning cost constitutes from 66 to 75% of the total cost. Thus, if the manning costs (direct personnel salaries and benefits) exceed those used in the study, the ATEC alternative will be even more cost effective, even at rapid digitization rates.

- The baseline ATEC alternative has the lowest operations manning requirement of the three alternatives for all digital/analog mixes. At high and low rates of digitizing transmission EFASR is higher by 20 and 32% respectively.

- It is concluded that ATEC can reduce tech control personnel by 39% (in a 74% digital environment); full digitization of the DCS backbone transmission without tech control automation would reduce tech control manning by up to 47%; and, finally, the combined effect of automation and digitization would reduce tech control manning by up to 57%.

e. Observations. The study addressed the savings in tech controller manpower through implementing the automation of tech control functions and the digitization of the DCS backbone transmission system. Maintenance on the three alternative automation systems was addressed but not considered significant in that the manning requirements were quite low compared to operational manning requirements. Maintenance manning requirements for the DCS were considered only in relation to the manpower reductions resulting from changing from analog to digital. No consideration was given to supervisory or support personnel, reduction of communications equipment maintenance time due to fault isolation/detection, or other manning and cost factors that the ATEC could impact.

The results of the analysis present evidence that there would be appreciable manpower savings and cost benefits in automating tech control functions. In addition, even greater savings could be realized by converting the DCS transmission backbone to digital.

The contractor recommends further studies such as the in-depth system-wide impact of digitization and automation; a complete life-cycle cost analysis to further quantify the cost advantage of the baseline ATEC; and application of the queueing-theoretic approach to manpower savings extended and generalized to other DCS subsystems and to utilization of manpower loading factors.

8. GTE SYLVANIA INC., "DIGITAL NETWORK CONTROL COST BENEFITS STUDY," FINAL REPORT SUPPLEMENT (27 OCT '77)

a. Background. This study is primarily concerned with the cost/benefit for Digital Network Control (DNC) subsystem. However, it is included in this overview pertaining to ATEC for several reasons. First, the ATEC is included as an element in each of the alternative DNC configurations analyzed in the study. Secondly, the relationship and application of ATEC in the DNC configuration and the post 1984 digital world is defined and depicted. Finally, the study addresses the basic issue of cost/benefits due to automation of technical control functions.

This study was conducted for DCEC in accordance with contract No. DCA 100-76-C-0064 (Task 9) by GTE Sylvania Inc. Electronic Systems Group (Eastern Division). The report (supplement) summarizes the results of a study to investigate the cost benefits of Digital Network Control (DNC).

The initial study (Tasks 1 through 8) was concerned primarily with developing the DNC requirements, concept, applications, algorithms and cost. An add-on to the basic contract (Task 9 - cost benefits analysis) had the following objectives:

- Specify and quantify those DNC operational benefits capable of analysis.

- Determine the optimality of the DNC design and application resulting from the first eight tasks when examined in the framework of total network costs.

- Examine the dependence of DNC hardware on ATEC for control and quantify any cost relationships.

- Compare and contrast the five DNC alternatives and the baseline system in order to recommend the most cost effective approach for augmenting DCS system control with DNC capability.

c. Description. The specific alternatives considered were based upon planned European DCS for the post-1984 time-frame, a channel reassignment capability for T1 digital groups (DNC-A), automation of the AUTOSEVOCOM II interface (DNC-B), and the AN/TSQ-111 (CNCE) limited channel reassignment function (CRF). The DNC-A deployment permits a network controller to establish a channel between any two first level multiplexers in the network and provides for a general circuit rerouting/reconfiguration capability without the need for manual patching. The application of DNC-B to the baseline provides for automation of the AUTOSEVOCOM II interface but does not provide any significant improvement in network configuration flexibility. The CRF application to the baseline, similar to DNC-B, is directed only at automating the AUTOSEVOCOM II interface.

The DCS Baseline against which each of the DNC alternatives was compared consisted of 90 transmission nodes interconnected by 100 digital links. Twenty-nine of the stations were unmanned, 20 were staffed by both technical controllers and maintenance personnel, and 41 were staffed by maintenance personnel only. The switching complement (AUTOSEVOCOM II) included four AN/TCC 39's and 26 digital concentrators. The ATEC equipment in the baseline consisted of 3 sectors, 9 nodes and 59 stations. The total numbers of technical controllers and maintenance personnel in the baseline system were 235 and 498 respectively.

Six alternatives were analyzed with respect to life cycle costs. Alternative 1 was the baseline system and alternatives 2 through 6 represented the baseline system augmented by various DNC elements. Each alternative was considered with and without a supporting ATEC deployment. It was noted that the baseline system did not include all equipment and manpower that would be deployed at those DCS stations considered. Accordingly, the life cycle cost derived for the baseline is not intended to be an absolute measure of its cost, but a gauge against which to compare each of the DNC alternatives. Also noted was the fact that the manning for satellite and switch facilities was assumed to be the same for the digital network as for the present analog network. However, the numbers of technical controllers and maintenance personnel at the Digital facilities were derived from the analog data base by assigning them in the same ratio as the number of digital links to analog links.

Three general areas were addressed for potential DNC cost benefits: manpower savings, hardware savings, and circuit mileage savings. The manpower savings stem principally from automating and remoting the network reconfiguration and circuit restoration functions. Hardware savings were due primarily to the elimination of rechannelization and a more efficient AUTOSEVOCOM II interface.

Circuit mileage savings were the result of minimization of transmission route backhauling and the general positive impact of channel reassignment on transmission capacity utilization.

The cost/benefit impact of automation was estimated through a queueing analysis similar to that used in DCEC TR3-77, "O&M manning studies". Further, many of the inputs for the manning and technical controller analysis were derived from TR3-77 and the Computer Science Corporation's Time and Motion Study performed at Croughton and Hillingdon (AF Contract F19628-73-C-0220, Mar '74).

The procedure followed in the analysis was: first, model the Technical Control Facility and calibrate the model; next, determine the impact of automation on the model parameters; and finally, exercise the model for the various parameters defined. The technical control modeling, including the operations and services performed, was consistent with the model developed in the DCEC TR3-77 study. In the preparation of the model, DCAC 600-60-1 was used in structuring the three major cost categories: research and development, acquisition, and operation and maintenance.

d. Results. Tables XIV through XIX provide the computational results of the analysis pertaining to personnel adjustments; table XX shows the cost of control equipment; tables XXI and XXII give the Life Cycle Cost (LCC) calculations and the resultant LCC's for all alternatives; and Figures 5 and 6 depict in bar graphs the 10 year differential life cycle cost relative to the DCS baseline system with and without ATEC. Figure 7 shows the tradeoff of controllers versus the technical control facility availability for the AUTOVON class facilities. The tables and graphs are described and commented upon in the following paragraphs.

Table XIV shows the impact of the ATEC and DNC-A on the arrival rate of the stochastic events and the service times of the technical control functions considered in this study. Only the ATEC affects the arrival rate because of its trending capability. Trending will operate by detecting an out-of-tolerance condition before it becomes a failure. Thus, this would be a preventive maintenance action and not a technical controller action. The extreme percentage range for the circuit restoration and fault clearing operation (20-80%) shown for the DNC-A is primarily due to the limitation on automatic circuit rerouting. A failure of the first level multiplexer, local loop or a node isolation will prevent the DNC-A from implementing an automatic reroute. The DNC-B and CRF alternatives were not included in this chart in that they do not have an impact on the technical control functions.

Tables XV through XIX show the technical control and maintenance manpower adjustments associated with each alternative to the DCS baseline system. The manpower adjustments derive from three sources: automation of the Technical Control Facility; an increase in the amount of corrective maintenance to be performed; and automation of the technical control functions performed by maintenance personnel at locations with no technical controllers. The preventive maintenance was assumed in this study to be unchanged by the introduction of automation. The effect of automation on corrective maintenance is to increase the manpower level as shown in Table XVII. Table XVIII reflects the reduction of maintenance personnel performing technical control functions at sites not manned with technical control personnel. Table XIX consolidates the various adjustment figures from Tables XV through XVIII and presents them as the total personnel reductions or increases for each alternative to the baseline system.

Table XX shows the cost of the control equipment, ATEC interface, and ATEC hardware associated with each alternative to the DCS baseline. The control of the DNC hardware requires hierarchical structure which is physically integrated into the planned system control subsystem. ATEC provides this structure. Without ATEC, a separate hierarchical control structure would be required for the DNC alternatives. This is reflected in the difference in the cost for the control/ATEC interface equipments with and without ATEC.

Table XXI is a summary of the Life Cycle Cost (LCC) computations associated with each alternative to the DCS baseline system. The cost includes escalation and discounting but not an adjustment for the AUTOSEVOCOM II circuit mileage savings. R&D costs are included only for the DNC and CRF hardware. For the purpose of this study, ATEC and DCS baseline equipments are assumed to have been previously developed. Thus, only an acquisition cost was included for these LCC calculations. The baseline system acquisition and O&M cost do not incude all the equipment and manpower deployed at those DCS stations considered in this study. Accordingly, these costs are intended only to be a basis or gauge against which to compare each of the ATEC, DNC, and CRF alternatives. The Life Cycle Cost (LCC) is the sum of the R&D, acquisition, and Case 1 or Case 2 O&M costs.

Table XXII shows the LCC figures developed above modified to include the AUTOSEVOCOM II circuit mileage cost savings associated with the DNC-B and CRF alternatives. Figures 5 and 6 present in graphic form the numerical results shown in Table XXII. These graphs show the differential life cycle cost relative to the DCS baseline system. Figure 5 compares the alternatives for Case 1, which considers the maximum manpower reduction likely through automation.

Figures 6 compares the alternatives for Case 2, which serves to place a lower bound on the impact of automation.

Figure 7 provides an interesting graph in that it reflects similar results obtained in the DCEC TR 3-77 study. The basis for GTE's evaluation of the technical controllers manpower reduction was determining the tradeoff between controllers and the expected technical control facility availability. This is indentified as the Figure of Merit E(n) (see section 6.a above for derivation). Figure 7 shows the tradeoff for the AUTOVON class switches for Case 1. The horizontal line in the figure represents the baseline system Figure of Merit E(A) obtained during the model calibration. This reflects the current standard of operation.

TABLE XIV. IMPACT OF AUTOMATION ON TECH CONTROL MODEL

	Arrival Rate (Reduction)	Service Time (Reduction)	
OPERATION	ATEC	ATEC	DNC-A
Circuit restoration and fault clearing (1)	7-14%	5-15%	20-80%
Assistance to other facilities	0	40%	4-10%
Reporting	0	60%	0

NOTE: These figures indicate the minimum and maximum reductions based on the most pessimistic and optimistic assumptions.

TABLE XV. TECHNICAL CONTROL PERSONNEL ADJUSTMENT SUMMARY

ALTERNATIVE		CASE 1	CASE 2
BASELINE	a	0	0
	b	- 78 (-33%)	-46 (-20%)
DNC-A	a	- 78 (-33%)	- 6 (-2.5%)
	b	-143 (-64%)	-78 (-33%)
DNC-B	a	0	0
	b	- 78 (-33%)	-46 (-20%)
DNC-A&	a	- 78 (-33%)	- 6 (-2.5%)
DNC-B	b	-143 (-64%)	-78 (-33%)
CRF	a	0	0
	b	- 78 (-33%)	-46 (-20%)
DNC-A	a	- 78 (-33%)	- 6 (-2.5%)
& CRF	b	-143 (-64%)	-78 (-33%)

CASE 1: MAXIMUM MANPOWER REDUCTION
CASE 2: MINIMUM MANPOWER REDUCTION
a. WITHOUT ATEC
b. WITH ATEC

NOTES: (1) Total number of control personnel in base system equals 235.
(2) Negative figures/percentages reflect personnel reduction from baseline.

TABLE XVI. CORRECTIVE MAINTENANCE MAN-HOUR REQUIREMENTS

ALTERNATIVE	WITHOUT ATEC	WITH ATEC
1. Baseline	3546	3937
2. DNC-A	3857	4216
3. DNC-B	3499	3886
4. DNC-A and DNC-B	3799	4154
5. CRF	3557	3943
6. DNC-A and CRF	3814	4174

TABLE XVII. CORRECTIVE MAINTENANCE MANPOWER ADJUSTMENTS

ALTERNATIVE	WITHOUT ATEC	WITH ATEC
1. Baseline	0	+23 (+4.6%)
2. DNC-A	+19 (+4%)	+41 (+8%)
3. DNC-B	-2 (-0.4%)	+20 (+4%)
4. DNC-A and DNC-B	+15 (+3%)	+37 (+7%)
5. CRF	0	+24 (+5%)
6. DNC-A and CRF	+16 (+3%)	+38 (+8%)

NOTES: (1) Total number of maintenance personnel in baseline system equals 498.

(2) Negative and positive figures/percentages reflect the decrease or increase of personnel from the baseline.

TABLE XVIII. MAINTENANCE MANPOWER ADJUSTMENTS DUE TO AUTOMATION OF TECHNICAL CONTROL FUNCTIONS

ALTERNATIVE		CASE 1	CASE 2
BASELINE	a	0	0
	b	-14 (-3%)	-14 (-3%)
DNC-A	a	-14 (-3%)	0
	b	-28 (-6%)	-14 (-3%)
DNC-B	a	0	0
	b	-14 (-3%)	-14 (-3%)
DNC-A &	a	-14 (-3%)	0
DNC-B	b	-28 (-6%)	-14 (-3%)
CRF	a	0	0
	b	-14 (-3%)	-14 (-3%)
DNC-A	a	-14 (-3%)	0
& CRF	b	-28 (-6%)	-14 (-3%)

a: Without ATEC
b: With ATEC
Case 1: Maximum Manpower Reduction
Case 2: Minimum Manpower Reduction

NOTES: (1) Total number of maintenance personnel in baseline system equals 498.
(2) Negative figures/percentages reflect personnel reductions from baseline.

TABLE XIX. TOTAL DCS BASELINE PERSONNEL ADJUSTMENTS

ALTERNATIVE		CASE 1	CASE 2
BASELINE	a	0	0
	b	- 69 (-9%)	-37 (-5%)
DNC-A	a	- 73 (-10%)	+13 (+2%)
	b	-130 (-18%)	-51 (-7%)
DNC-B	a	- 2 (-0.2%)	- 2 (-0.2%)
	b	- 72 (-10%)	-40 (-5%)
DNC-A & DNC-B	a	- 77 (-10%)	+ 9 (+1.2%)
	b	-134 (-18%)	-55 (-8%)
CRF	a	0	0
	b	- 68 (-9%)	-36 (-5%)
DNC-A & CRF	a	- 76 (-10%)	+10 (+1.3%)
	b	-133 (-18%)	-54 (-7%)

a: Without ATEC
b: With ATEC
Case 1: Maximum Manpower Reduction
Case 2: Minimum Manpower Reduction

NOTES: (1) Total number of control and maintenance personnel in the baseline system equals 733.
(2) Negative and positive figures/personnel reflect the decrease or increase of the total (maintenance and control) personnel from the baseline.

TABLE XX. CONTROL EQUIPMENT/ATEC INTERFACE UNINSTALLED HARDWARE COSTS

ALTERNATIVE		CONTROL EQUIPMENT/ ATEC INTERFACE ($K)	ATEC HARDWARE ($K)
BASELINE	a	0	0
	b	0	626
DNC-A	a	341	0
	b	65	626
DNC-B	a	34	0
	b	0	626
DNC-A	a	341	0
&DNC-B	b	65	626
CRF	a	34	0
	b	0	626
DNC-A	a	361	0
& CRF	b	85	626

a: Without ATEC
b: With ATEC

NOTES: (1) ATEC hardware cost supplied by DCEC.
(2) Control equipment/ATEC interface equipment cost supplied by GTE, based on current vendor prices.

TABLE XXI. PRELIMINARY LIFE CYCLE COST RESULTS (1) (6) (7)

ALT. (2)		(4) R&D ($M)	(4) ACQ ($M)	O&M (3) CASE 1 ($M)	O&M (3) CASE 2 ($M)	LCC (3) (5) CASE 1 ($M)	LCC (3) (5) CASE 2 ($M)
BASELINE	a	-	64.371	161.981	161.981	226.351	226.351
	b	-	77.709	159.890	163.306	237.600	241.016
DNC-A	a	1.014	76.109	157.414	166.595	234.537	243.718
	b	1.014	88.855	156.372	164.806	246.241	254.674
DNC-B	a	1.008	64.154	161.176	161.176	226.339	226.339
	b	1.008	77.420	158.514	162.366	236.943	240.795
DNC-A &	a	1.698	76.550	156.657	165.838	234.905	244.086
DNC-B	b	1.698	89.296	155.614	164.048	246.609	255.042
CRF	a	1.008	65.138	161.842	161.842	227.989	227.989
	b	1.008	78.405	159.830	163.246	239.243	242.659
DNC-A	a	2.022	76.847	156.944	166.125	235.813	244.994
& CRF	b	2.022	89.597	155.902	164.335	247.521	255.955

NOTES:
(1) Excludes impact of circuit mile savings.
(2) a - without ATEC, b - with ATEC.
(3) Case 1 - maximum manpower reduction; Case 2 - minimum manpower reduction.
(4) R&D cost for the DNC system incurred over a 5-year period (1978-82) - cost for the acquisition (acq) including installation incurred over 1 year (1983).
(5) 10-year life cycle cost for the years 1984-1993.
(6) All costs are discounted for FY 1977 using a 10% discount rate.
(7) Life cycle cost techniques consistent with DCA Circular 600-60-1.

TABLE XXII. LIFE CYCLE COSTS MODIFIED TO INCLUDE COST/BENEFIT RESULTS

ALTERNATIVE		CASE 1 ($M)	CASE 2 ($M)
BASELINE	a	226.351	226.351
	b	237.600	241.016
DNC-A	a	234.537	243.718
	b	246.241	254.674
DNC-B	a	225.929	225.929
	b	236.534	240.386
DNC-A &	a	234.298	243.479
DNC-B	b	246.002	254.436
CRF	a	227.816	227.816
	b	239.070	242.486
DNC-A	a	235.640	244.821
& CRF	b	247.348	255.782

NOTES: (1) Includes circuit mileage cost savings.
(2) a - without ATEC, b - with ATEC.
(3) Case 1 - maximum manpower reduction; Case 2 - minimum manpower reduction.

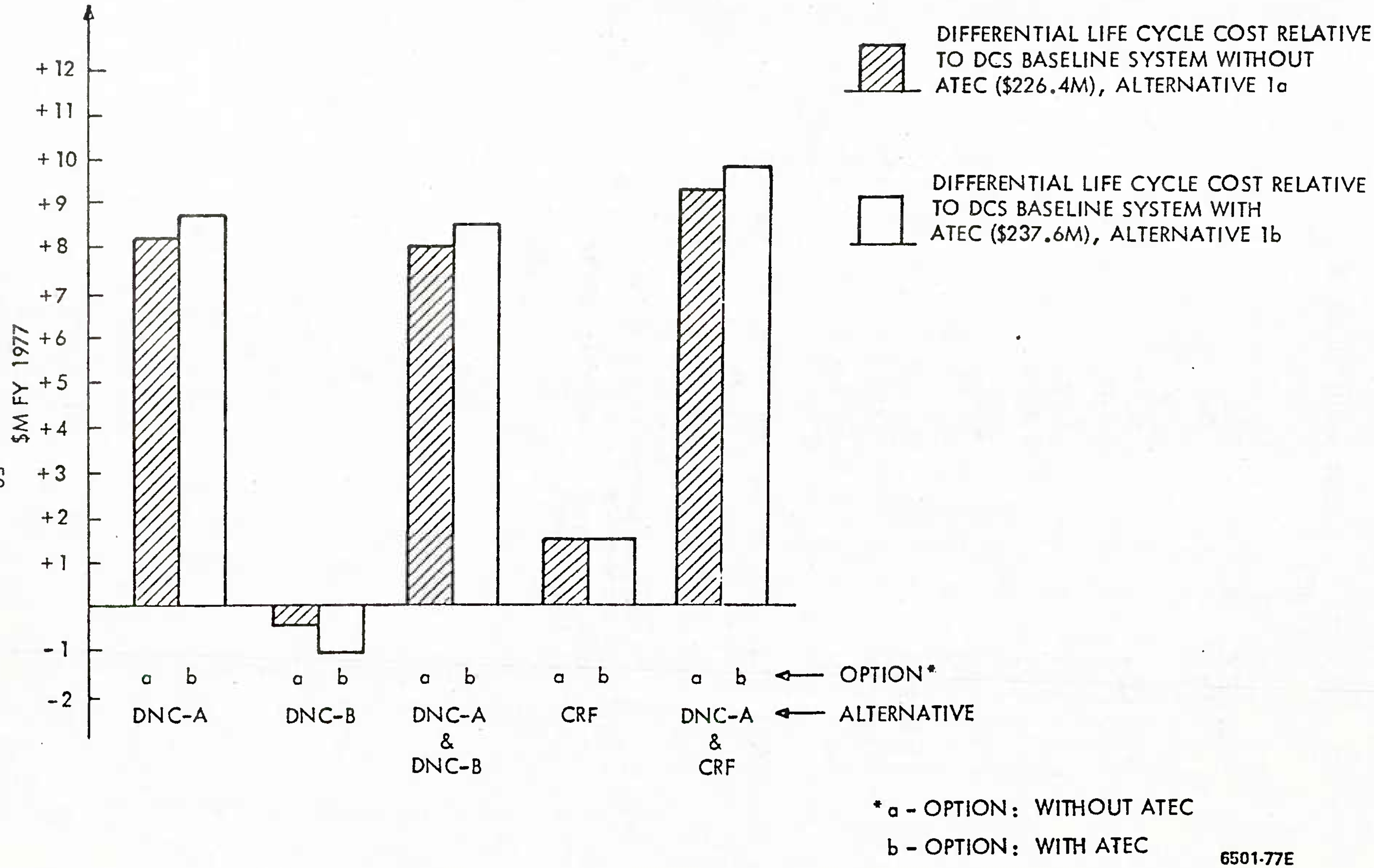

Figure 5. 10-Year Differential Life Cycle Costs, Case 1

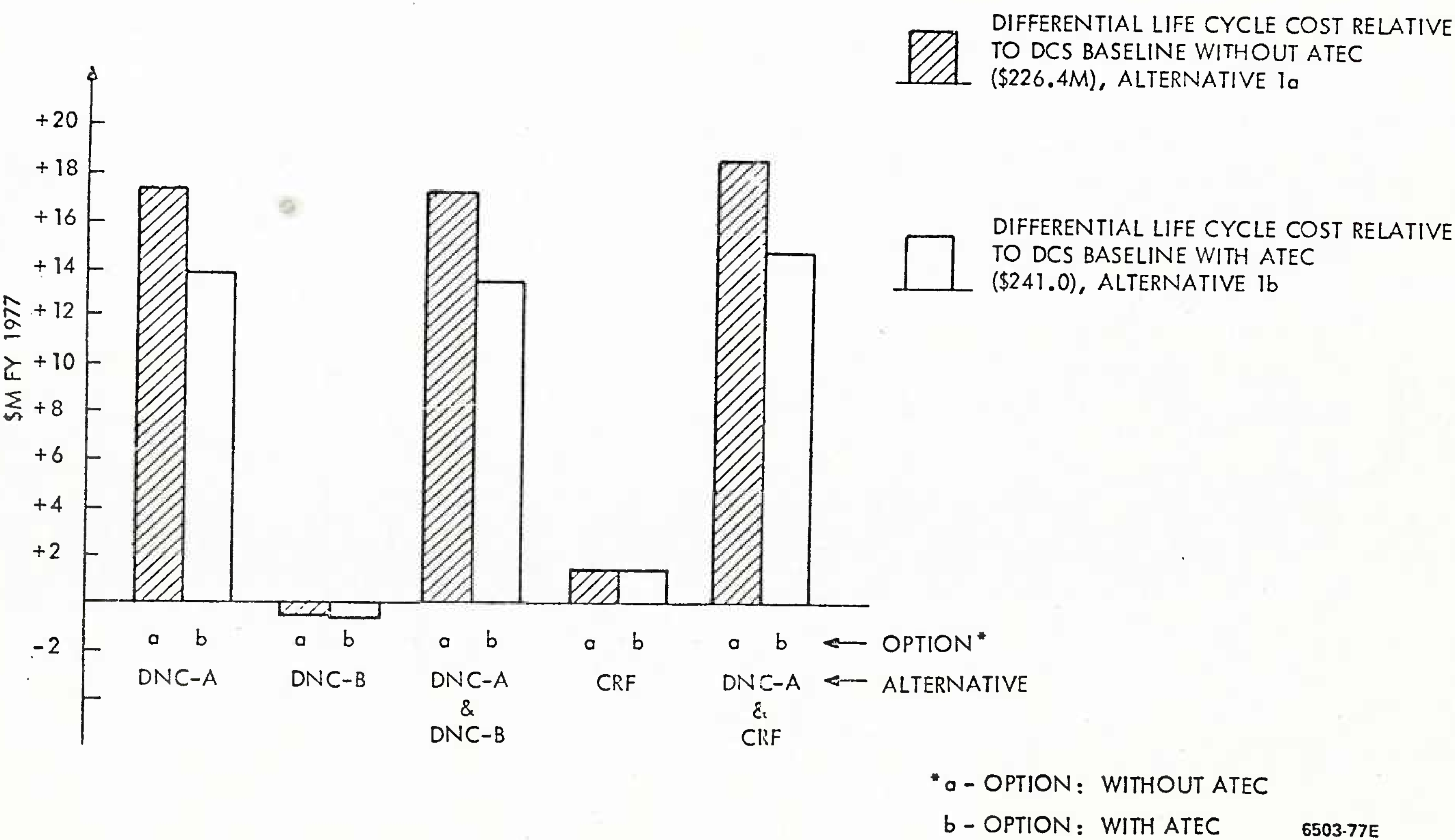

Figure 6. 10-Year Differential Life Cycle Costs, Case 2

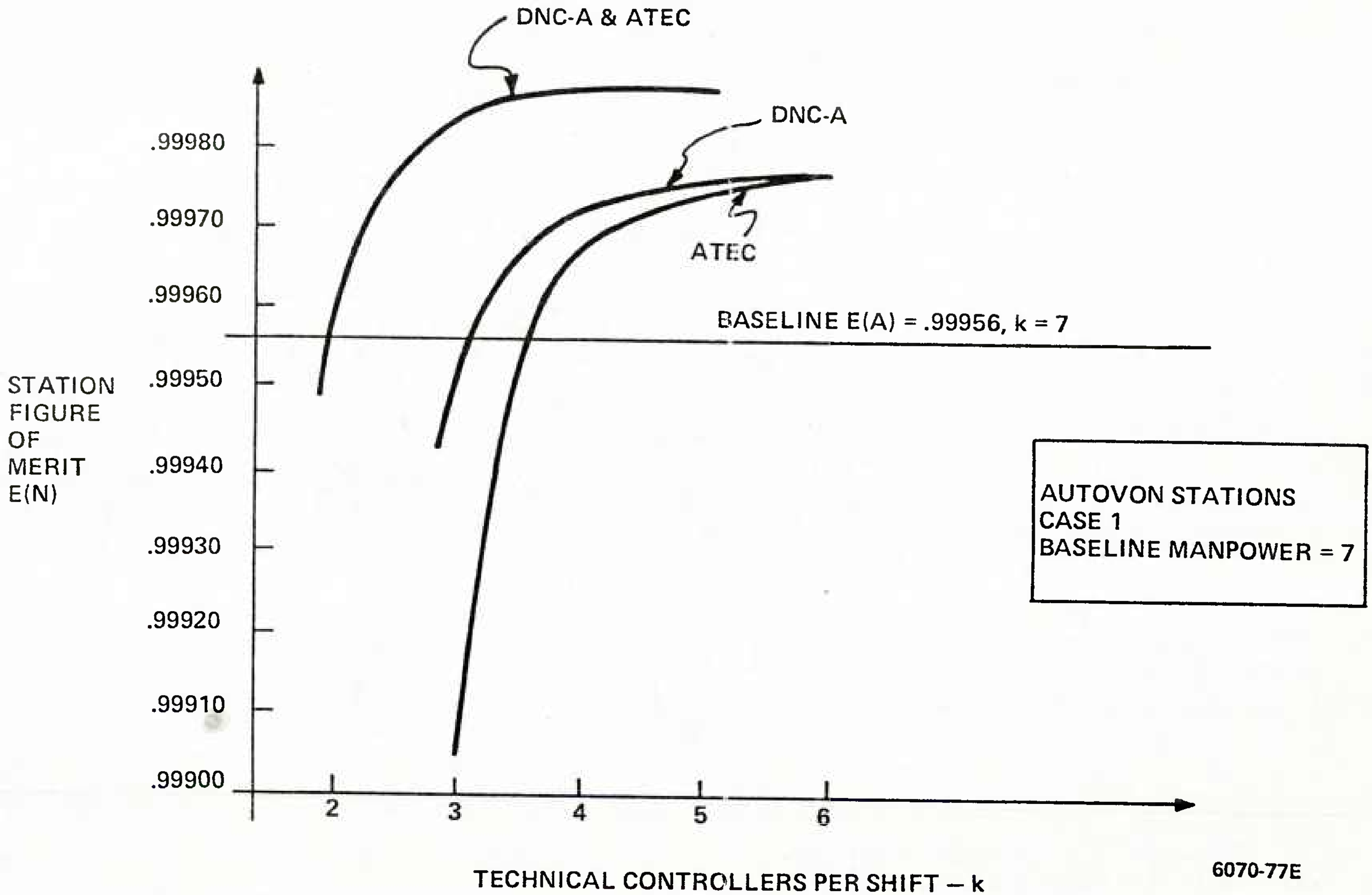

Figure 7. Technical Control Manpower - Station Availability Tradeoff

d. <u>A summary of the significant results follows</u>:

- The net equipment change for each alternative, with the exception of DNC-B without ATEC, results in a net increase in maintenance personnel.

- When ATEC is deployed, the only control costs incurred are those required to interface DNC with ATEC; when ATEC is not deployed, the cost of an overall hierarchical structured network must be incurred when deploying the DNC.

- All three channel reassignment devices (DNC-A, DNC-B and CRF) provide the potential to reduce channel mileage to less than that required by the baseline.

- Neither DNC-B nor the CRF when examined alone (without ATEC or DNC-A) provides sufficient automation in the technical control facility to play a role in the automation analysis.

- The ranking with respect to total life cycle cost is, in increasing order of cost, DNC-B, Baseline, CRF, DNC-A/DNC-B, and DNC-A/CRF.

e. Conclusions. GTE Sylvania's conclusions were as follows:

- In general, automation results in a decrease in the number of technical controllers and maintenance personnel required.

- ATEC reduces the cost associated with the deployment of DNC hardware.

- DNC-A and ATEC provide complementary functional capabilities and are desirable as a joint deployment.

- With respect to AUTOSEVOCOM II interfacing, DNC-B is clearly superior to either the presently planned manual interface used in the baseline or the CRF interface alternatives.

- Joint deployment of ATEC with DNC-A/DNC-B is considered to be more cost effective than either deployed alone.

f. <u>Observations</u>. This study differed from the others in that the baseline model is that configuration planned for the European DCS for the post-1984 time frame. The baseline model was considered both with and without ATEC deployment. The study then proceeded to consider specific DNC alternative applications to the two baseline configurations. The objectives were to ascertain and compare the manpower savings of technical controllers and maintenance personnel, and the hardware and circuit-mileage savings derived from the various combinations.

The study concluded that the ATEC is an important element in the future digital DCS network control because it provides the hierarchical network configuration required to interface and interconnect the DNC elements. Further, it provides the essential centralized control of the channel reassignment functions. Without the ATEC it would be necessary, in order to deploy the DNC elements, to develop and incur the additional cost of a control hierarchy, i.e., a system similar in many respects to the ATEC configuration.

The study attempted only to compare benefits among the various DNC alternatives and among these alternatives and the baseline configurations. It was not oriented specifically to the ATEC or to the benefits that could be derived from its deployment. Thus, for the development of the system control applicable not only to the analog DCS but to the evolving digital DCS systems, this study provides a basis for planning purposes.

9. AIR FORCE ANALYSIS

a. Introduction. Several Air Force activities (ESD, AFTEC, and AFCS) planned and conducted various phases of an ATEC cost/benefit analysis on equipment in an operational environment. The various plans addressed herein were intended to provide the criteria for the test and data acquisition, and the objectives for the cost/benefit analysis. The technical control/maintenance functions and the areas impacted by ATEC, delineated in these plans, were more directly related to the current operational DCS than those considered in the four studies reviewed.

Two Air Force briefings presented to the senior representatives of the three Military Departments and DCA and the AFCS Benefits Analysis Report provide an insight into the Air Force analyses effort. The first briefing (27 Mar '78) was oriented towards the ATEC enhancement requirements for the LRIP ATEC equipments. The second briefing (8 Aug '78) was oriented toward the LRIP decision. In that the latter included basically the same cost/benefit data, in summary form, as that presented in the previous briefing, it will be omitted from further consideration. The briefing being considered was comprised of two distinct presentations. The first was oriented towards the principal findings of the ATEC JIOT&E. The second addressed the ATEC Benefits Analysis conducted by AFCS. The following provides the significant points of the presentations and the AFCS Benefits Analysis Report:

b. AFTEC Presentation. The basis for the ATEC analysis was the data from the JIOT&E effort and the review of the ATEC LRIP performance specification. The analysis was oriented primarily toward the subscriber (user) service, technical controllers' workload, and the Technical Evaluation Program (TEP) personnel.

The primary functions considered in the workload reduction calculations were status monitoring, fault isolation, quality control, performance monitoring, recordkeeping, reporting, and service restorations.

In reviewing the proposed LRIP ATEC specifications, as part of the analysis, certain operational and system design deficiencies were discovered. These deficiencies were in the areas of communications problem isolation, system status information to serving technical Control facilities, and coordination. The deficiencies were considered of such magnitude and had such an adverse effect on the system's effective operation that it was concluded the benefits of the proposed ATEC were not sufficient to justify production. System design changes were proposed directed toward eliminating the deficiencies and providing an enhanced system with appreciable increase of benefits.

It was estimated that the LRIP ATEC, as specified in the performance specification, would result in the following:

- 19% to 30% reduction in technical controllers' workload.
- Reduction of 284 to 458 technical controllers out of 1600 (1982 partial digital world).
- Reduction of 28 TEP personnel.
- Increase of 377 personnel for ATEC operation, software maintenance, hardware maintenance, and data base maintenance.
- Total manpower net change worldwide ranging from an increase of 65 to a decrease of 109 people.

It was estimated that if the ATEC system defined by the Dec '77 specification was enhanced as proposed by AFTEC, the following would result:

- 49% reduction in technical controllers' workload.
- Reduction of 752 technical controllers worldwide.
- Reduction of 70 TEP personnel.
- Increase of 366 personnel for ATEC operation and support.
- Total manpower net change worldwide would be a reduction of 456 personnel.

c. AFCS Presentation. The basis for the AFCS analysis comprised the results of earlier studies, a recent survey of technical control workload, and information made available from the JIOT&E test team. The analysis was oriented toward manpower savings, other benefits such as DEB Fault Alarm System (FAS), System Control, Standardization, and enhancement of the proposed LRIP ATEC system.

The analysis indicated the following:

- ATEC will absorb and supplant the rudimentary FAS of DEB yielding a cost avoidance benefit by obviating the need for developing a permanent system for the follow-on DEB stages.

- ATEC is the basis for the automated system control, achieving DoD approved system control goals, and improving the survivability of the DCS. Not implementing ATEC would have a deleterious effect on these elements.

- The very nature of ATEC will foster a degree of standardization within the DCS not currently achieved, e.g. measurement techniques, reporting, and data base update.

The analysis indicated that a number of enhancements should be made to the proposed ATEC design which would have a direct impact on manpower savings and subscriber (user) service. The enhancements are in the areas of data base updates, ATEC interface with non-standard DCS configurations or equipments, improved troubleshooting capability, coordination between technical control facilities, reporting and recordkeeping, and displays (man-machine).

Manpower savings were estimated only for the latter three enhancements. Using as a baseline worldwide population of 1600 technical controllers (1982 partial digital world), the estimated reductions were:

- Coordination - 12% personnel reduction (192 technical controllers).

- Reporting, recordkeeping - 7% personnel reduction (112 technical controllers).

- Displays, man-machine - 2% personnel reduction (32 technical controllers).

- Total technical controllers net change worldwide would be a reduction of 336 personnel.

d. Conclusions (Air Force)

(1) AFTEC. The analysis to determine the applicability of the LRIP ATEC specified in the performance specification pertaining to the subscriber (user) service and technical controllers' workload showed that the benefits derived would not be sufficient to justify production or deployment. The test results showed that the LRIP design with enhancements would provide substantial benefits in manpower savings and subscriber (user) service.

AFTEC recommends that the LRIP ATEC design should be enhanced to maximize potential for improvement in manpower savings and subscriber (user) service.

(2) AFCS. Agrees with AFTEC that the ATEC as currently specified in the LRIP specification would result in a system offering only minor manpower savings. Also, that by incorporating several enhancements in the ATEC system design, substantially higher payoffs could be realized. Their analysis results substantiate the idea that the estimated savings must be expressed with a wide range of uncertainty.

AFCS recommends that the ATEC be procured and that efforts to incorporate the proposed enhancements be pursued vigorously.

e. Air Force Communications Service, Automated Technical Control (ATEC), Benefits Analysis, June '78

(1) Background. Preliminary JIOT&E test results as reported by the AFTEC test team raised a number of urgent questions focusing on manpower benefits derived from ATEC. From January through March 1978, AFCS conducted an accelerated ATEC System Benefits Analysis primarily to answer these questions and to provide a major input to the LRIP decision. The results of the analysis were given in the 27 March '78 briefing discussed earlier. The Benefits Analysis Report documents the overall conclusions presented at the briefing.

(2) Description. The ATEC Benefits Analysis was primarily a desk-top effort. It represents a study of the impact of ATEC, both with and without enhancements, on technical control manpower within certain limitations. The limitations pertain to the difference between the LRIP and the JIOT&E test bed; possible difference between the LRIP and the follow-on; and the extent of European DCS digitization during deployment. The study was conducted in consultation with the JIOT&E test team personnel, MITRE personnel who participated in developing the ATEC LRIP specification and experts in functional areas such as the Performance Monitoring Program (PMP). Sources of Information were the current (baseline) technical control manning criteria, previous studies, on-site visits and a current survey of representative Air Force technical control facilities. The specific approaches, procedures and elements considered for this study are listed below:

- The initial effort addressed the current workload in conjunction with what ATEC could do to assist the technical controller.

- The basic approach was to compare Air Force LRIP sites in 1982 with and without ATEC equipments.

- The factors examined at the Air Force LRIP sites (with and without ATEC) were technical control manpower and workload requirements, technical control operational procedures, maintenance workload, added software maintenance workload, added computer ATEC) maintenance workload, test equipments and the relationship of ATEC to other programs.

- To derive the worldwide manpower requirements, the probable effect of ATEC on the current technical control manpower standard was examined. This was in lieu of extrapolating directly from the manpower authorization changes within the Air Force LRIP sites to a worldwide deployment projection. The extrapolation technique was not considered feasible because of the differences in the worldwide technical controls and the number of Air Force LRIP sites manned with Technical Controllers.

(3) Results. Tables XXIII through XXVI extracted from the report present the results of this study in tabular form.

Table XXIII shows three major areas of technical controllers direct labor in which factors addressed by previous studies and the manning standard are included. The first column of figures shows the percentage of manhours determined from previous studies. The second column shows the values derived from a representative sampling of 17 Air Force technical control facilities (TCF). The third column represents a refined set of values with weighting factors combining the first two columns and drawing upon knowledge gained throughout the analysis.

Tables XXIV A, B and C depict the impact LRIP ATEC (without enhancements) would have on each workload category based on pessimistic and optimistic interpretation of the LRIP specification. Again as in Table XXIII, the three categories addressed are the previous studies, Air Force TCF survey and the weighted combining of these two. The values in column 1 are similar to the percentage value in Table XXIII but are shown in manhours. The second and third columns reflect the percentage and number of manual baseline manhours respectively that remain after ATEC implementation. The fourth column shows the range of pessimistic to optimistic percentage of manpower savings.

Table XXV provides a detailed breakout of estimated TRI-service manpower add-backs to support the world-wide deployment of ATEC without enhancements. These add-backs are required to support node and sector operations; sector data base maintenance and on-site programming support; node and sector hardware maintenance; depot-level computer/software support; DCA data base maintenance; and indirect and overhead manpower requirements.

The gross estimate for world-wide manpower savings attributable to deployment of ATEC without enhancements was based on the following:

- The Worldwide population of technical controllers (1982) will be 1540 for ATEC sites.

- The low range manpower savings of 30.3 percent (Table XXIV.C) was considered the most probable for ATEC worldwide deployment without enhancements.

- A reduction of 40 percent of the potential seventy Technical Evaluation Program (TEP) personnel savings could be reasonably achieved for ATEC worldwide deployment without enhancements.

The manpower savings calculations developed in this study for ATEC without enhancement were:

- 1540 Tech Controllers X 0.303 = 467 manpower spaces saved.

- 467 Tech Controllers - 378 add-backs = 89 manpower spaces saved.

- 89 manpower spaces + 28 TEP manpower spaces = 117 total manpower spaces saved.

The approach used to quantify potential manpower benefits solely attributable to ATEC enhancements differed somewhat from the methodology used in estimating manpower savings for ATEC without enhancements. It was not possible to ascribe incremental manpower savings to individual enhancement items. Thus as an alternative, AFCS performed a Macro-analysis of the ATEC incorporating the total set of proposed enhancements. An estimation was made of manpower savings expected from the enhanced ATEC and these projected savings were compared with the estimates developed for ATEC without enhancements. This procedure was then coupled with a "reasonableness" test inorder to minimize the effect of the many unknowns in the predictive process. This test addressed how might the estimated savings be distributed. It also addressed the distribution fit with what had been learned previously throughout the analysis, relating to the technical controller's workload, shortcomings in the ATEC specifications, ATEC fault detection/isolation capabilities, JIOT&E test results, and so forth.

Table XXVI shows the results of the benefit analysis pertaining to manpower savings for the enhanced ATEC. The table shows the three manpower groupings in which additional benefits may be expected: station level technical controls, add-backs to support the enhanced ATEC system, and TEP personnel. The workload categories are the same as the analysis of the ATEC without enhancements. The manual baseline direct hours allocations are the same as the combined data values (Table XXIV C). For comparison purposes, the pessimistic numerical values from the same table are included in parenthesis.

TABLE XXIII. BREAKOUT OF MAJOR TECHNICAL CONTROLLER FUNCTIONS AS A PERCENTAGE OF DIRECT HOURS

Workload Category	Previous(1) Studies	AF TCF Survey (Avg)	Combined Data Using All Sources
Quality Assessment	20	31.0	23.0
Reporting & Record Keeping	25	21.5	23.0
Unscheduled Workload	55	47.5	54.0
	100%	100%	100%

Note 1. Previous studies are:

a. AFCSR 26-3 extract, Manpower Standard for Functional Code 3803, Technical Control, 15 May '75.

b. Honeywell Corporation, Technical Control Facility Systems Analysis, 8 June '76.

c. DCEC Technical Note No. 5-75, A System Control Alternative Analysis, Apr '75.

d. Computer Sciences Corporation, Analysis of Technical Functions for Croughton and Hillingdon, Mar '74.

TABLE XXIV. DETERMINATION OF MANPOWER REDUCTIONS (ATEC WITHOUT ENHANCEMENTS)

A. Using direct workload distribution derived from previous studies.

WORKLOAD CATEGORY	Manual Baseline Direct Hrs	Percent Remaining after ATEC		Remaining Workload with ATEC		Range of Manpower Savings
		Pessi-mistic	Opti-mistic	Pessi-mistic	Opti-mistic	
Quality Assessment	20.0	35%	19%	7.0	3.8	
Reporting & Record Keeping	25.0	80%	50%	20.0	12.5	
Unscheduled Workload	55.0	80%	50%	44.0	27.5	
Total	100 Hours			71.0 Hrs	43.8 Hrs	29%-56.2%

B. Using direct workload distribution derived from AF TCF survey.

WORKLOAD CATEGORY	Manual Baseline Direct Hrs	Percent Remaining after ATEC		Remaining Workload with ATEC		Range of Manpower Savings
		Pessi-mistic	Opti-mistic	Pessi-mistic	Opti-mistic	
Quality Assessment	31.0	35%	19%	10.9	5.9	
Reporting & Record Keeping	21.5	80%	50%	17.2	10.8	
Unscheduled Workload	47.5	80%	50%	38.0	23.8	
Total	100 Hours			66.1 Hrs	40.5 Hrs	33.9%-59.5%

TABLE XXIV. (Cont'd)

C. Using combined data.

Quality Assessment	23.0	35%	19%	8.1	4.4	
Reporting & Record Keeping	23.0	80%	50%	18.4	11.5	
Unscheduled Workload	54.0	80%	50%	43.2	27.0	
Total	100 Hours			69.7 Hrs	42.9 Hrs	30.3%-57.1%

TABLE XXV. ADD-BACK MANPOWER SPACES TO SUPPORT WORLDWIDE ATEC DEPLOYMENT (ATEC WITHOUT ENHANCEMENTS)

	Sector(8)	Nodes(25)	Other/Depot
Operations	56	200	0
Software Maintenance	16	4*	19**
Hardware Maintenance	0	50	0
Data Base Maintenance	32	0	1***

Total Add-Backs = 378 Manpower Spaces

*Two nodes are planned not to have associated sectors and will therefore require organic on site programmers.

**Software support provided by the Communications Computer Programming Center CCPC (AFCS).

***DCA data base maintenance; DCA estimates manpower impact as ranging from a savings of 3 to an add-back of 5. The mid point of this range was used for computational purposes.

TABLE XXVI. TRI-SERVICE MANPOWER SAVINGS FOR ENHANCED ATEC AND ATEC WITHOUT ENHANCEMENTS (IN PARENTHESIS)

STATION LEVEL TECHNICAL CONTROL WORKLOAD

Workload Category	Manual Baseline Direct Hours	% Remaining After ATEC *	Remaining Workload with ATEC *	Hrs/% Saved *	Total Manpower Saved *
QA	23.0	30.0 (35.0)	6.9 (8.1)	16.1(14.9)	247.9)229.5)
Reports & Records	23.0	50.0 (80.1)	11.5 (18.4)	11.5(4.6)	177.1(70.8)
Unscheduled Work	54.0	60.0 (80.0)	32.4 (43.2)	21.6(10.8)	332.6(166.3)
Total	100 Hours		50.8 (69.7)	49.2(30.3)	758(467)

*Pessimistic figures shown in parenthesis from Table XXIV C

ADDBACKS

	SECTORS	NODES	OTHER/ DEPOT	TOTAL ADDBACKS
Operations	40 (56)	200 (200)	0 (0)	240 (256)
Software Maintenance	16 (16)	4 (4)	24 (19)	44 (39)
Hardware Maintenance	0 (0)	50 (50)	0 (0)	50 (50)
Data Base Maintenance	32 (32)	0 (0)	1 (1)	33 (33)
Total	88 (104)	254 (254)	25 (20)	367 (378)

TECHNICAL EVALUATION PROGRAM SAVINGS

ATEC with Enhancements 70

ATEC without Enhancements. . . . .(28)

NET TRI-SERVICE MANPOWER SAVINGS. 461 (117)

f. Observations. The two presentations in the Air Force briefing and the AFCS Benefits Analysis had basically the same theme oriented toward justifying an enhanced ATEC system. The arguments presented were that in order to deploy an ATEC system that would provide manpower reductions, certain design changes to the proposed LRIP ATEC would be necessary. The arguments presented to support the enhancement requirements also indicated that substantial benefits and manpower savings would result in deploying a properly designed ATEC system.

The presentations and report again support the basic premise that by automating the technical control functions, certain operational benefits, manpower reductions, and potential cost savings will ensue. Of particular interest was the observation pertaining to the impact on the overall system control planned for the future DCS. Also of particular interest was the idea of integrating the fault alarm system of DEB into the ATEC design, thus avoiding a duplicate system and additional cost. Both of these are considered extremely important for inclusion in any cost/benefit analysis pertaining to ATEC.

III. COMPARISON OF STUDIES

In section II, several test plans and studies were reviewed and a summary of their objectives and results were given. In this section, these studies are examined to determine their scope, depth, and adequacy. The various elements addressed in the studies are identified and examined for their contribution to determining the costs/benefits. The studies to be considered are Honeywell, DCEC TR 3-77, Booz-Allen, GTE, and AFCS Benefit Analysis.

Table XXVII lists a number of elements used for the various system models and analyses and shows the particular elements used in each of the studies considered herein. The tabulation clearly shows a specifc group of elements most frequently considered in all or most of the studies. The following identifies and groups these common elements:

- Selected DCS facilities in the European area comprised the basic system configuration.
- Technical controllers were the predominant group for manpower savings considerations.
- Maintenance personnel were considered in the majority of studies but to a much lesser degree than technical controllers.
- The predominant technical control functions considered were QA, fault isolation, circuit restoral, assistance to other facilities (coordination), and reporting.
- The multiserver queueing model was the basic approach for analyzing the technical control operational functions.
- ATEC procurement and limited hardware/software support costs were included in the cost/saving calculations.

There are other significant factors that can be derived from the elements tabulated in Table XXIII. The following provides a grouping of the more important elements and associates the specific study that addressed them:

- Honeywell considered some limited support personnel, commercial rebates, test equipments, analog DCS (with DEB), 1982 timeframe, and compared the manual technical control operation with the ATEC operation for cost savings.

- DCEC TR 3-77 considered the analog DCS, the 1975 timeframe, and the before/after technical control automation (not necessarily ATEC) for cost savings.

- Booz-Allen considered unmanning sites savings, channel reassignment techniques, DCS digitization rate impact on ATEC cost savings, analog to digital DCS transition (3 stages), 1982-1992 timeframe, and compared the ATEC with the DEB EFASR system for cost savings.

- GTE considered hardware/circuit mileage savings, channel reassignment techniques, a primarily Digital DCS, the post-1984 timeframe, and compared the DNC systems (with and without ATEC) against the baseline DCS.

- AFCS Benefit Analysis examined the data derived from the JIOT&E performed on the pilot production ATEC assets in Europe and other data from on-site surveys, manning tables and other studies. Further, the ATEC LRIP specifications were examined and the total findings integrated. Finally, the LRIP ATEC system with and without enhancements oriented towards manpower savings were compared.

TABLE XXVII. MAJOR ELEMENTS OF ATEC STUDIES

Analysis Element	Honey-well	TR 3-77	Booz-Allen	GTE	AFCS
1. TCF Personnel	x	x	x	x	x
2. Node/Sector Personnel	x				x
3. Sched. Maint. Personnel	x		x	x	
4. Mngmt/Overhead Personnel	x				x
5. Test Eqpt Spt. Personnel	x				
6. ATEC HW/SW Support	x		x		x
7. Training	x				
8. Commercial Rebates	x				
9. Manual Test Eqpts.	x				x
10. Hardware Savings				x	
11. Ckt Mileage Savings				x	x
12. Unmanning Sites Savings			x		
13. ATEC Procurement Cost	x		x	x	
14. UK w/DEB (1982)	x				
15. European Configuration		x	x	x	
16. 1975 Time Frame		x			
17. '82/'87/'92 Stages (Analog to Digital)			x		
18. Post-1984 Timeframe				x	
19. Number of Facilities	13	14	16	90	17
20. Meas. of Effectiveness (MOE)		x	x		
21. Multiserver Queueing Model (T/C)		x	x	x	
22. Manual-ATEC Comparison	x			x	x
23. Before/After Tech Contrl Automation		x			
24. ATEC/EFASR (DEB) Comparison			x		x
25. Dig. Ntwk. Contrl (DNC)/ ATEC Comparison				x	
26. Quality Assurance/Contrl	x	x	x		x
27. Performance Mon. Prog.		x	x		x
28. Level Discipline (Signals)	x				x
29. Route Assessment	x				x
30. Fault Isolation	x	x	x	x	x
31. Ckt Restoral	x	x	x	x	x
32. Assistance to Other Facilities (Coordination)		x	x	x	x
33. Logs		x			x
34. Reporting	x	x	x	x	x
35. Standby (Idle) Time		x		x	
36. Primarily Analog System (DCS)	x	x			

TABLE XXVII (Cont'd)

	Analysis Element	Honey-well	TR 3-77	Booz-Allen	GTE	AFCS
37.	Primarily Digital System (DCS)			x	x	
38.	Tech Contrl Automation (not ATEC)		x			
39.	Baseline/Limited ATEC, EFASR		x			
40.	3 DNC System/6 Config. (w/wo ATEC)				x	
41.	Channel Reassignment			x	x	
42.	DCS Digitization Rate Impact			x		
43.	Extrapolated Worldwide Cost/Benefits	x				
44.	Breakeven Cost Est.	x	x			
45.	Ten Year Life Cycle Cost			x	x	
46.	Extrapolated 132 Site Cost/Benefit			x		
47.	JIOT&E ATEC Configuration					x
48.	Compared ATEC with and without Enhancements					x
49.	1982 Time Frame					x
50.	Air Force LRIP Sites					x
51.	Worldwide ATEC Deployment Manpower Savings					x

The information available at this point provides a basis for developing some generalizations pertaining to the five studies being considered. This includes the individual value they may have in ascertaining the savings of ATEC and the potential value they may have in relation to the overall system control program.

The following subsections examine each study for those factors that will provide a basis for making a judgment as to its contribution towards the ATEC cost/benefit analysis objectives:

1. HONEYWELL

This study provided an analysis to determine if ATEC would be cost effective. In the computations, both the savings and the additional costs incurred were included. The criterion for effectiveness was the difference in cost between the manual DCS and the DCS automated with ATEC.

The DCS (UK 1982) model, technical control functions and areas impacted by ATEC, provided a workable baseline for the analysis. Although the DCS model included digital facilities (DEB), it appears that the emphasis was placed on those functions associated with the analog world.

The cost factors for personnel and equipment were conservative and the results of the calculations for savings in these areas were considered reasonable. However, the commercial rebates estimates appeared to be extreme. These estimates were reviewed with DECCO and other activities concerned with leased practices and tariffs. The consensus was that this was not a realistic estimate.

The study provided only a superficial treatment of the areas impacted by ATEC. Thus, the calculated savings at best could only be considered rudimentary estimates. However, this study is meaningful and useful in that it does provide evidence that savings can be derived from some degree of technical control automation by eliminating certain manual functions.

2. DCEC TR 3-77

This study was oriented towards showing the relationship between technical control performance level, number of technical controllers, degree of technical control automation, and the breakeven cost for the automation. Basically, the study was a theoretical and mathematical approach but takes on some degree of the real DCS characteristics by application of operational data from 14 representative technical control facilities in the European area. The portion of the DCS considered was represented by a multiserver queueing model with a first-in first-out queueing discipline reacting to such things as interarrival and service time distributions.

The study focuses on a narrower view than the Honeywell study in that it concentrates on technical control manning levels only. However, it does again provide a positive indication that savings can be derived from automating technical control functions. A conclusion developed in the study noted that it is useful for analyzing manning levels and predicting which proposed improvements involving automation of technical control functions should prove to be cost effective.

3. BOOZ-ALLEN

This study was oriented toward showing the effect on cost, manning requirements, and operational effectiveness of the technical control facilities when varying the degree of technical control automation and the rate of the DCS change from analog to digital.

The earlier work performed by DCEC and the queueing theoretical approach (TR 3-77) was used in this study. The queueing approach was refined and augmented by the PERT network analysis technique in conjunction with a DoD-approved operational analysis procedure. The PERT model of a station-level Technical Controller's activity is based on an event-oriented PERT network on a 24-hour cycle. This enhancement, in conjunction with the selected DCS model, technical control functions, and areas impacted by automation, provided a good baseline for the analysis. In addition, the three automation alternatives coupled with the DCS analog to digital conversion considerations enhanced and appreciably broadened the depth of the study.

The study provided a comparative analysis of savings derived from the proposed ATEC, an ATEC with reduced capabilities, and the DEB EFASR systems. However, the more important aspects of the analysis appear to be the impact on the savings because of the timing of the DCS digitization and the influence of inflation on manpower cost over a specified period. The latter has a major impact on the life cycle cost (LCC) of any given system and weighs heavily on the relative savings of the manpower reductions versus automation equipment cost.

4. GTE SYLVANIA

This study was directed towards determining the most cost effective approach for augmenting the DCS system control with a Digital Network Control (DNC) capability. The impact of the automation was estimated through a queueing analysis similar to that used in the DCEC study (TR 3-77). The earlier work performed by Computer Sciences Corporation relating to the analysis of the technical control functions for DCS stations Croughton and Hillingdon was used extensively. The LCC computations included an appreciable number of cost factors for operating, maintenance, and support functions. The selected DCS model and the operational functions considered in conjunction with the items noted above provided a good baseline for the analysis.

The study provided a comparative analysis of ATEC with various DNC configurations. The study was primarily oriented toward the savings derived from the DNC applications. However, the analysis did indicate that ATEC is an essential element in the DNC configuration in that it provides the required hierarchical control structure.

5. AFCS BENEFITS ANALYSIS

This study examined and compared the manpower savings that could result from deployment of ATEC with and without enhancements. It was noted that the original LRIP specifications did not focus upon reduction of manpower but focused primarily on improving the quality and responsiveness of the DCS to users. The ATEC enhancements, designed to increase manpower savings without sacrificing quality, were proposed to ensure fielding a cost-effective system. The results of the analysis and the comparison indicated that an appreciable increase in manpower savings could be gained by incorporating the enhancements in the LRIP equipment design.

Although the focus of the analysis was directed toward identifying and assessing potential manpower savings, other potential benefits were also identified. These included.

- ATEC as the basis for DCS system control.
- ATEC as the basis for improving DCS survivability.
- ATEC as a contributor to WWOLS ADP Improvement Program.
- ATEC as a basis for standardization within the DCS.
- ATEC obviating the need for developing a permanent Fault Alarm System (FAS) for the follow-on DEB stages.

The sources of data for this analysis were primarily from the operational environment, test data from the ATEC pilot production assets and ATEC LRIP specifications. Additional sources included data from previous studies, current manning tables, recent site surveys and experts in QA and ATEC LRIP specifications. Effectively, this analysis, in comparison to the other studies considered herein, was based more on the real-world DCS, ATEC and the operational environment. Consistent with the results of the other studies, the conclusion is that ATEC (especially with enhancements) will appreciably reduce technical control manpower requirements.

IV. APPLICATIONS OF AUTOMATION BY COMMERCIAL COMPANIES

Important sources of information pertaining to the benefits and cost savings of automation are the commercial operating telephone and communications companies. These organizations are competitive and profit motivated and have continuously explored those areas that provide improved service and, at the same time, have reduced their operating, maintenance, and overhead cost. Many examples are cited in technical publications and are readily discernible in the operation and design features of the various communications facilities.

A typical organization is the C&P Telephone Company. Since 1971, they have had an increase of 18% in telephone service requirements; yet the number of workers has dropped 19% as new equipment has been installed. Previously, it took 50 people to run one switching center. Now, primarily due to the automation of testing, diagnostic routines, fault isolation, and the modular design of equipment components, it takes approximately 10 people to run a switch. This kind of evidence and proof of the value of automation can be found throughout the industry.

In this section, some of the automated control and test systems employed or being tested by the operating companies of General Telephone and Electronics (GTE) and the Bell Telephone System are examined. The scope of the technological advancements of these systems, the basic requirements dictating automation, the feasibility of automated systems, the depth of the cost/benefit analyses, and the benefits derived from employing the automated systems are also examined.

The following subsection addresses GTE's automation approach and involvements. The handouts supplied during their "Communications Briefing" presented at DCA Headquarters (21 Dec '77) are the source of the information.

1. GTE AUTOMATION APPLICATIONS

a. Operations Support Systems. GTE has centralized the administrative and maintenance operations through the establishment of the Switching Service Organization (SSO) and the Switching Services Operations Service (SSOC). GTE considers the development and introduction of operations support systems essential to increase the effectiveness of the people who operate, administer, and maintain the communications equipments and networks.

The operations support systems are minicomputer based systems that can carry out functions such as testing, centralized central office alarms, carrier alarms surveillance, recordkeeping, and record changes to data bases.

Such systems are attractive because by automating and centralizing important facets of administration and maintenance, they can provide reductions in operating expenses and improvements in service.

Arguments presented for utilizing minicomputer based systems instead of wired logic circuits were:

- Measuring or monitoring of systems normally found in telephone switching and transmission facilities becomes more flexible.
- Software based systems can be developed quickly and less expensively and can perform complex functions that would be too expensive and too difficult to maintain if done with hardwire logic or manually.
- Flexibility of minicomputers allows programmers to incorporate sophisticated functions such as analysis, data retrieval, results compilation, and reporting at a reasonable cost.

b. Control Office Maintenance Planning System (COMPS). This system provides an automated method for planning, scheduling, assigning, keeping records, and measuring all routine maintenance and troubleshooting operations associated with each central office. It provides the vehicle for the accumulation of current operational costs by functions. The primary functions of the system are:

- Generate a maintenance planning report for each central office indicating which routines are scheduled for each month.
- Generate a monthly job assignment ticket for each routine that is scheduled for the succeeding month.
- Process the routine completion data from the job assignment tickets back into the system.
- Process the trouble data from the trouble tickets containing the source and disposition of the troubles and cause of the equipment failures.
- Provide various output reports for tracking routine completions and the comparison of budgeted hours with actual hours spent.

- Generate maintenance cost for each type of system at each central office.

- Process facility administration expense data and summarize it by function and location.

- Provide various output reports on the facility administration functions pertaining to cost, labor efficiency, and requirements.

The end product produced by the COMPS is a data base of maintenance and facility administration costs to aid in justifying capital expenditures in electronic (automation) conversion systems.

c. Traffic Data System (TDS). The TDS comprises central office data collection devices, minicomputer based Central Data Collection (CDC) for polling, and downstream batch processing software to summarize data and print reports. The original objective of the TDS was to increase the availability of data for traffic engineering and management functions. It was found to be a vital support system for operations to enable spotting congestion problems. The ultimate objective is to have a capability of remotely obtaining some form of administrative traffic data from all central offices.

The traffic data collection methodology is seen as moving towards centralization and automation through use of a single CDC, located in a support center to poll all TDS installations. This arrangement enables concentration in one location of the specialized expertise required to operate the CDC and the eventual elimination of manual handling of central office traffic data.

d. Telemetry Control System (TCS). One of the most important tools for centralizing maintenance effort is the TCS, which enables status monitoring and subsequent control actions from a remote location. Surveillance of remote locations consists of monitoring status inputs from in-place monitoring equipments at the site.

The TCS is capable of accepting and transmitting control signals when direct positive control actions must be taken on a particular item of equipment at the site. The telemetry system feeds into the Switching Service Operations Center (SSOC) over dedicated lines, data networks, or the Direct Distance Dialing (DDD) network as dictated by the specific installation.

The development of a TCS that will function in a wide range of application will enable:

- Unmanned operation of many installations, resulting in large savings.

- Centralization and consolidation of network management expertise with resulting manpower savings.

- Enhancement of coordination and network management control.

- Dispatch of personnel to the sites only when troubles develop, precluding routine trips to perform status checks.

- Fewer costly breakdowns since continual surveillance is possible.

e. Remote Alarm and Surveillance Systems (RASS). The purpose of the system is to provide sufficient data from remote sites to permit the sites to operate unattended and allowing the concentration of maintenance personnel at a central point.

The operational concept is that through minicomputer analysis of alarms by site, type, and time of occurrence, the appropriate action can take place and the proper people dispatched to correct the problem. The system consists of a minicomputer capable of storing and processing the alarm data, a display panel with audible and visual indicators, and a CRT for information display and recording.

f. Computerized Local Loop Testing System. A prototype system using the 4-TEL equipments manufactured by Teradyne Central underwent an extensive field test and evaluation (1975-1977). General Telephone Company of Wisconsin conducted the technical evaluation; General Telephone Company of Florida evaluated the operational impact; and an intercompany task force conducted the applications and benefits analysis. As a result of the evaluations and analyses, GTE has adopted the system as a GTE Standard (MIRSC 126-75).

The system is a computer-driven plant surveillance system designed to test local customer loops and analyze detected trouble conditions. The system comprises Central Office Line Tester (COLTS), CRT terminal, and a Serving Area Minicomputer (SAC). One SAC, with its associated COLTS, can handle approximately 100,000 lines.

The SAC performs the following functions:

- Services request from display terminal (CRT).

- Controls the COLTS and initiates the routines.

- Assimilates routing results and generates reports.

- Reports various 4-TEL system malfunction (self test).

The COLT performs the following functions:

- Under control of its own minicomputer, executes line test after receiving a start command from the SAC.

- Performs single line test upon operator demand.

The field test proved the system to be effective in at least the following applications:

- Customer trouble report administration

- Customer line insulation routing

- Service order verification

- Trouble report verification

- Cable throw verification

- Cable trouble analysis

- Line termination equipment analysis

- Service office management.

The value of the system was broken down to three broad categories.

- Customer service

- Increased revenues

- Reduced repair expenses.

The criterion for the cost and payback analysis was that the volume and labor expenses must be matched against the cost of the 4-TEL system in order to determine the profitability of the investment. The cost and payback analysis was based on two separate inputs:

- The results and cost of the Tampa Bay West 4-TEL installation.

- Use of 4-TEL to consolidate repair center operations in a typical GTE Company.

The Tampa Bay West 4-TEL analysis developed the following information:

- The computations reflected the worst case conditions and assumptions.

- The comparison of system cost and projected labor savings identified a financial return of twice the investment cost as a uniform annual equivalent.

- The analysis indicated a breakeven point at slightly more than 6 years, using a 10 year life cycle cost basis.

The consolidated repair center operations analysis produced the following:

- The "typical" GTE Company consists of 460,000 lines and 16 test centers with an average of 3 testboard operators per center.

- The same 460,000 lines could be administered by use of the 4-TEL system in five test centers on a 24 hours-a-day basis with a net reduction in tester team size of 10 employees (20% reduction).

The two studies showed conclusively that the investment in the 4-TEL system is highly cost-effective for the GTE telephone companies.

g. Other Operations Support Systems. Systems being considered by GTE are described below:

(1) Remote Monitor and Control System (RMCS). A minicomputer based system for the monitoring and control of GTE Automatic Electric Electronic switching systems at the SSOC. This system is undergoing field trial.

(2) Centralized Automatic Reporting on Trunks (CAROT). A minicomputer based system providing centralized testing access to trunk circuits originating at remote central offices. The control point can be located in the SSOC and can direct the automatic testing of approximately 15,000 trunks each night.

(3) Carrier Surveillance System (CSS). A minicomputer based system providing real-time monitoring of carrier integrity, reporting of fault conditions, and tracking and analysis of intermittent carrier span problems. This system is envisioned as the foundation of a Centralized Carrier Restoration and Control Center located in the SSOC.

(4) Trunk Records and Testing System (TRTS). This system is basically a centralized on-line trunk record retrieval system and an

executive control system that is tied into a remote trunk test system. The executive control system would provide programmed testing instructions; communicate with the trunk record retrieval system; and accept, catalog, and distribute trunk testing results for follow-up by repair forces.

(5) Trouble Analysis Control (TAC). This is basically a computer technology to provide instantaneous analysis of trouble tickets derived from customer service complaints. With the growth of complex switching networks, it became an almost impossible task for the service people to locate the problems with the little information available. One step forward was the development of TAC centers that consolidated the trouble tickets and provided more sophisticated analysis techniques. In the late 1950's, efforts were initiated by several telephone utilities to explore possibilities of computerizing this process. Through many variations, it has now developed into a most sophisticated, efficient, and effective system. The trouble tickets are captured at the source (traffic office) and transmitted to a time sharing computer (GTEDS/UCSS VI) located at the TAC center. A massive amount of data is processed resulting in trouble patterns. The TAC analyzers refer the trouble patterns to the proper switchrooms. They in turn pinpoint and repair the equipment causing the problem.

(6) Service Observation Systems. The system provides the most complete single measure of end-to-end switching. It employs a centralized minicomputer and has the following characteristics:

- Capable of remote, unmanned operation.
- Capable of determining complete call disposition, e.g., completion, busy, no answer, or no ring.
- Capable of determining at what point a call failed so that trouble patterns can be developed.
- Capable of summarizing disposition data into reports as well as analyzing equipment irregularities so that corrective action can be taken.
- Capable of polling the remote (call selector) sites for data acquisition.

2. AT&T AUTOMATION APPLICATIONS

The following addresses AT&T's (Bell System) automation approach and involvements. The source of this information is the Bell Laboratories Record.

Similar to GTE, the Bell System operating companies have adopted the operational support systems - minicomputer based systems that carry out functions such as centralized testing, plant surveillance, and recordkeeping. The early work performed by the Bell System pertaining to automation has produced a solid foundation for development and implementation of a large number of operational support systems. The following discussion provides a brief chronology of events that has led to the current status of the systems development and implementation:

- A minicomputer experiment in Faulkner, Maryland (1968) was performed to see if continuous analog measurements of a TD3 radio system could reduce routine maintenance and predict failures.

- An experiment was performed in Sacramento where a minicomputer was used to monitor and control telecommunications sites along the California Aqueduct project.

- In late 1970 and early 1971, a field test was conducted on systems that performed automated measurements on carrier equipments and trunks.

- Success of these and other earlier projects led to Bell Laboratories' development of standard measurement or monitoring systems which contained their own minicomputers.

- Toward the end of 1971, about 15 major developments using minicomputers were proposed that, in turn, dictated some level of standardization and uniformity.

- In early 1972, AT&T, Western Electric, and Bell Laboratories formed a tri-company task force to look into the establishment of Bell System standards and policy for minicomputers.

- By the end of 1972, most of the task force's work was completed. An important result was the creation of a Bell Laboratories Standard Book, "Documentation Guidelines for Minicomputer Applications in Standard Systems." This document addresses most problem areas associated with minicomputers. Perhaps one of the most important results of the task force is that it created an increased awareness of minicomputer applications associated with operations support systems within the Bell System.

In view of the functional similarities to many of the GTE minicomputer operation support systems previously described, only a listing and brief description of a few systems developed by the Bell System will be given.

a. E-Telemetry System. This is the Bell System standard telemetry system in support of remote sensing, data acquisition, and centralized control and maintenance. The present system has evolved through three generations of equipment. The first and second generation equipment supported status reporting and control systems and provided independent telemetry for general application. The third generation (E2A) equipment acts as an interface between minicomputer operations support systems and the E-Telemetry network. This telemetry network and its interfacing element have provided the means of interconnecting and integrating various measurement, surveillance, control, and record storage system.

b. Maintenance Systems That Primarily Perform Measurements

(1) Centralized Automatic Reporting on Trunks (CAROT). This computer-controlled centralized system automatically tests up to 100,000 trunks in an area, analyzes the results, and sorts these into categories. A new version of this system includes subscriber loop testing and other applications. Currently the systems deployed automatically test under computer control over 30% of the Bell System trunks.

(2) Carrier Transmission Maintenance Systems (CTMS). This system performs automatic in-service tests to replace the manual routine measurements. This operations support system also offers computer-aided, centralized facilities that greatly enhance an individual's ability to isolate troubles within an office or at other locations.

(3) Loop Maintenance Operations System/Mechanized Loop Testing (LMOS/MLT). This is a third generation automated test system. The LMOS stores and processes line-card records and tracks current trouble reports, analyzes past troubles, and starts the loop testing process. The MLT tests the customer loops. The LMOS is a network of general purpose computers and minicomputers with a large central processor at the hub. The minicomputers are connected to the central computer and the MLT controller with high speed data links. The system can handle 5 million customer lines.

c. Maintenance Systems That Primarily Perform Surveillance and Control Functions

(1) Surveillance and Control of Transmission Systems (SCOTS). This is a centralized computer controlled system that automatically monitors and supervises the broadband transmission facilities including microwave radio, coaxial cable carrier systems, and their associated terminal equipment. This operational support system makes it possible to consolidate the many alarm centers

currently monitoring the equipment into fewer central locations. By 1980 AT&T Long Lines expects to be monitoring all its unattended equipment for long haul broadband transmission with this centralized system. In addition, deployment of this system will reduce the number of attended equipment requirements resulting in a substantial increase in unattended equipment and sites.

(2) T-Carrier Administration System (TCAS). This is a computer controlled system installed at a central control station. It analyzes alarms, sectionalizes failures, and monitors transmission performance of T-1 networks. The system employs a minicomputer linked by the E-Telemetry system to carrier offices. It sectionalizes troubles to a specific terminal or span line and provides the maintenance personnel with the analysis report.

(3) Centralized Status and Alarm and Control System (CSACS). This is a computer controlled system located at a Switching Control Center (SCC) that monitors alarms from unattended step-by-step and cross-bar switching systems. The maintenance and administration activities formerly located in up to 16 switching centers can be consolidated in an SCC.

d. Recordkeeping and Administrative Systems

(1) Trunks Integrated Recordkeeping Systems (TIRKS). This is a computerized system that, among other inventory and recordkeeping functions, acts as a master data base for minicomputer operations support systems that carry out maintenance functions.

(2) Engineering and Administration Data Acquisition System (EADAS). This is a centralized computer controlled system that collects and computes network use data. It furnishes real-time reports for Bell System administrators and inputs data for computer programs that help in forecasting the use, and managing, of the network.

(3) Business Information System Customer Service/Facility Assignment and Control Systems (BISCUS/FACS). This is a large computer system that assigns facilities and equipments needed to connect customers for telephone service. This system is designed for an entire operating company area that typically serves 1 million customers. It handles 10,000 service orders a day and has a reference data base of 20 million records. The system provides the various departments of the company (directory, plant, etc) the information they need to accomplish their function. In effect, it automates time-consuming paperwork routines.

3. OBSERVATIONS

This overview of the application of automation by the commercial companies includes only a fraction of the automated systems actually in operation or being planned. Nevertheless, it shows that during the past 10 years, the magnitude of this effort, the technological advancements in the system designs, and the growth in applications of automation have been astronomical.

The basic requirement that dictated the use of automation was to enhance the ability of the operating companies in the areas of administration, operation, maintenance, and management of the telephone plants and transmission networks. The tremendous growth of the communications industry and its resources precluded manually performing many of the functions associated with these areas.

The alternative to manual operation is to employ automation techniques. This is essential in order to obtain accurate and timely information for the personnel in each area noted. It is further required to eliminate such things as manual testing, monitoring, control, and other manual functions that can be effectively automated.

Some of the obvious objectives of employing automated operations support systems are:

- Improving the effectiveness of the operations, maintenance, and management personnel.
- Improving customer service.
- Permitting unattended sites.
- Centralizing operations and maintenance.
- Reducing cost of operations, maintenance, administration, and management.
- Reducing loss of revenue by reducing service interruptions.

The predominant use of minicomputer based operations support systems and the arguments presented for supporting their use definitely established them as the preferable technique. The interpretation of the basic operational concept is that the minicomputer systems tie into the control centers and the data storage and retrieval centers via a telemetry network.

V. SIGNIFICANT FINDINGS AND CONCLUSIONS

1. SIGNIFICANT FINDINGS

In section III, the five studies considered herein were broken down into their respective components and a comparison was made of the contribution of each to the overall cost/benefit analysis objectives. A close examination revealed that only a comparatively small number of functions were considered pertaining to the technical control operations, DCS equipment maintenance, support elements, equipment savings, and other important and highly impacted areas. Generally omitted was any consideration of possible improvements in the operation and utilization of the DCS resources as a byproduct of technical control automation. A common thread that ran through all the studies was the consideration of basically the same technical control functions and the areas impacted by technical control automation. A common conclusion throughout the studies, based on the areas considered, was that a reduction in the number of technical controllers could result from automation. Other factors considered in different studies showed that maintenance and support personnel reductions, equipment savings, and circuit mileage savings could also result from technical control automation. From all of this, it was generally concluded that there could be a cost reduction in the operation and maintenance of the DCS by employing ATEC.

In section IV, the application of automation by commercial companies and the impact on their operations and cost savings were examined. Certain significant and predominant points were evident:

- Automation is essential to increase the effectiveness of the people who operate, administer, maintain, and manage the communications systems.
- Automation is essential to contain the rapidly increasing cost of maintenance, operation, and management.
- Automation is essential to ensure acceptable subscriber service and system performance.
- Proper application of automation reduces costs.

2. CONCLUSIONS

The five studies, in total, did produce meaningful results and provided through the analysis and computations, appreciable evidence that automating the technical control functions would be beneficial.

Probably of equal importance is that these studies provided a number of distinct scenarios of the DCS configurations and timeframes and applied cost/benefit analyses to them. This provided a broad understanding and perspective of the effect the composition of the future DCS could have on the automation configuration. In particular, the studies showed a variation of cost and manpower savings incurred with ATEC system in the different environments depicted. Thus, consideration should be given to those findings during the process of firming up the design of the LRIP ATEC system, and especially the follow-on full production design.

The presentations in the Air Force briefings and the AFCS Benefit Analysis Report demonstrated the need and value of the cost/benefit analysis during the system development phases. The review of the ATEC LRIP performance specification and the application of the JIOT&E test data revealed certain deficiencies in the proposed LRIP system design concept. This has provided the opportunity to develop a much improved and cost-effective system. This strongly indicates that continuous application of cost/benefit analyses, especially during the LRIP deployment period, could possibly weed out additional deficiencies. This should also ensure that the final production equipments will have been designed to the most cost-effective configuration by applying the proper operational and cost tradeoffs.

The commercial companies have accomplished appreciable research, experiments, test, analysis, and other actions necessary to prove the value of the automation concept. In addition, they have gained much experience in the field by incorporating extensive automation features in their operating facilities. Rather than reinvent the wheel, it would be beneficial to the government to take advantage of this technological advancement and apply those features, where applicable and feasible, to the DCS. Thus, consideration should be given, during the LRIP ATEC design and field test phases, to incorporating those features that have proven beneficial to the commercial systems and are applicable to the DCS.

A final conclusion is that the results of all the cost/benefit work considered in this overview provided strong evidence that the automation of DCS technical controls can be cost effective and operationally beneficial. The results of the commercial companies' automation work confirmed to a large extent the results of the studies and provides positive proof of the automation benefits. Thus, it would be of little value to continue with an in-depth cost/benefit analysis for the purpose of proving the benefits of automating technical control functions. It is recognized that greater in-depth analysis could possibly show other manpower savings such as maintenance, support, and management that could accrue from the ATEC. However, this appears to be more of a Manpower/Workload

Survey function for the purpose of adjusting site manning tables. Accordingly, the future cost/benefit analyses, rather than being broad in scope, should be oriented toward discrete and specific objectives similar to that noted in the second paragraph above.

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