# Computer change at the Westinghouse Defense and Space Center

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## INTRODUCTION

The Westinghouse-Baltimore Defense and Space Center is a military contractor of approximately 13,000 employees with sales billed in the neighborhood of one-quarter billion dollars annually. Computer operations are centralized with research, engineering, management science, and business data processing all being handled by the same facilities located in an Administrative Services Building nearby the two major Divisions of the complex but up to 60 miles away from other operations which it serves. At the present time the central computer is a UNIVAC 1108 with four connected UNIVAC 1004's, eight IBM 1050's and additional Friden Collectadata equipment which permit access to the 1108 from various remote and not so remote locations.

A status report on these facilities, however, is not the subject of this paper. My subject is *computer change* and in particular computer change from the point of view of an organization which has undergone fairly frequent and successful change.

The basic reasons for computer change are to *reduce costs* and *provide adequate computer capacity*. The demands of the rapidly changing technology of the defense business and the needs of its customers for machine processed information sometimes seem almost impossible to satisfy. However, it does not follow that the cost of computer processing must continue to climb. In fact, at the Westinghouse Defense and Space Center total costs for computer service have actually been reduced by nearly 40 percent during the past two years. This reduction has taken place in spite of the fact that the requirement has continued to grow. As a rule-of-thumb, by taking advantage of improved equipment, exploiting improved software and techniques and by more effective loading of equipment, it is possible to reduce per job computer costs by a factor of two every two years. In fact, the Westinghouse Defense and Space Center has used this rule-of-thumb as a guide for evaluating its performance over the past six years.

*Computer acquisition at Westinghouse*

At the Westinghouse Electric Corporation, we have developed over the years a fairly advanced computer acquisition procedure of which we are justly proud. We have centralized computer ordering. We treat the acquisition of computers as cost reduction projects. Divisions of the Corporation desiring computers are required to conduct a feasibility study culminating in a justification report. A procedure exists requiring the approval of the Division Manager, the Headquarters Management Systems Department, the Group Vice President to whom the Division reports, and for the most expensive models, the Corporate Capital Expenditures Committee. Our Headquarters Management Systems Department contains experienced computer specialists who assist the divisions in such deliberations. Reports have been issued describing our computer acquisition procedure, the cost reduction guidelines which must be met, and a checklist of items to be considered in the feasibility study and documented in the justification report. Among the items covered are the requirements that more than one computer supplier be considered and that the purchase or rent question be evaluated.

Additionally the Headquarters Management Systems Department negotiates contracts with the various computer manufacturers. These negotiations have resulted in several contractual conditions which have made computer change easier for the Westinghouse Divisions. These contractual conditions include:

1. 90-day cancellation option for complete systems;
2. 30-day cancellation option for individual units or subsystems;
3. Letters of intent and "pool" orders to facilitate delivery schedules; and

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4. Software modifications or special software requirements to meet local needs.

Through the use of cost reduction guidelines for computer projects and additional contractual conditions, Westinghouse management has allowed healthy growth of its computer systems and their usage, while continuing to maintain effective control of the equipment.

*Management guidelines*

Efficient and effective change requires adherence to certain *management guidelines* on the use of the computer systems. Some of the more important of these guidelines in effect at the Baltimore Defense and Space Center are as follows:

1. *Machine independent programming languages are used* with careful attention to modularity in system design. *Subroutines* are constructed in such a way that they can be used in more than one application without change.
2. *Data files* are established in a standard machine processable format so that these files can be effectively maintained and used for more than one information requirement.
3. *Follow-up analyses are performed as a standard part of any equipment acquisition as well as for each application implemented.* All too frequently a computer based information system is designed to provide information to solve a particular problem. It is essential that the information should stop flowing when the original problem has been solved. Exception reporting should be the rule rather than the exception. The emphasis and format of computer output should continue to change as necessary to respond to changing management needs.
4. *Backup arrangements are provided for all equipment.* It is generally not economically feasible to have sufficient in-house equipment to meet all emergency situations, but one can usually have a neighbor with compatible equipment that can serve as mutual backup. Organizations such as users associations help to foster individual local arrangements. Sharing of ideas as well as equipment can also result from such backup arrangements. Eventually with machine independent programming, it won't be necessary for the backup installation to have the same type of equipment.
5. New types of ADP Equipment should never be acquired until such time as an extensive *workload has been established on Service Bureau* or other equipment elsewhere. This means that the computer programs required will have been written and tested before new equipment is installed.
6. Follow-up of equipment and individual applications is emphasized via the project schedule technique. Evaluation and *monitoring of the total load* is also performed. Charts indicating hours of usage, number of runs being made, hours per shift of "distributable" use, and related usage figures are maintained and carefully examined to ascertain trends. The amount of time for re-runs and set-up is monitored and action taken to control any undesirable trend. Unlike other service costs, computer service costs per unit of work, when properly controlled, do go down.
7. USASI sponsored standardization efforts are carefully followed to be certain that the internal standards policy is consistent with USA Standards. Proposed USASI standards are regularly published in the Communications of the Association for Computing Machinery.
8. *New problem solving techniques are communicated to individuals* responsible for implementing new computer programs. We must be certain that all of our system design work and each new computer program is properly reviewed by senior personnel to check accuracy, conformity to standards and to make certain that poor techniques are not being used. Programmers don't like this, but other work is reviewed, why not computer programs? Individuals are given responsibility for the quantity and quality of their work. They are informed as to the total requirement and the individual Analyst/Programmer is made *responsible* for his individual effort.

*Westinghouse-Baltimore experience*

To be more specific now with respect to the Westinghouse-Baltimore Defense and Space Center, I have included three figures which illustrate our growth in computer usage and improvement in price performance. Figure 1 shows the decline in typical job cost. Figure 2 illustrates the reduction in average cost per equivalent IBM 7094 hour over the past six years. In spite of, or rather in part because of, a growth from 10,000 computer passes per month in 1962 to over 25,000 passes at the present time as illustrated in Figure 3, the average cost per typical job and the average cost per equivalent computer hour have easily met the goal of a factor of two cost decrease every two years.

During the past four years over 40 changes have been implemented to the Westinghouse-Baltimore facilities. Some of the changes involved only individual units or special features; however, during this period 12 computer systems were released and replaced by 10 new systems. One of these changes was for a mechanical replacement of a 1401 system which was replaced by

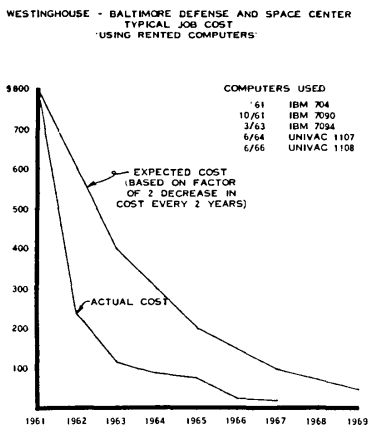


Figure 1—Westinghouse-Baltimore Defense & Space Center typical job cost (Using Rented Computers)

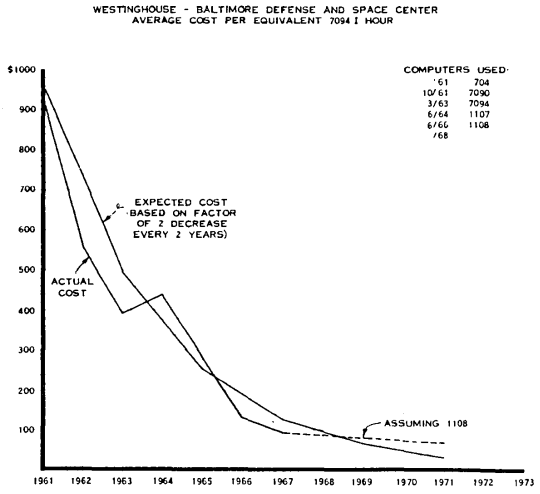


Figure 2—Westinghouse-Baltimore Defense & Space Center average cost per equivalent 7094 I hour

IBM when it could no longer be maintained. Most of the other changes were upgrading of 1401's to 1460's and finally to 360/30 systems. During the 4-year period, six 1401 systems and three 1460 systems were replaced or released. During the same period an IBM 7090 was upgraded to a 7094 which was later released. A UNIVAC 1107 was acquired and later replaced by an 1108. The present configuration consists of an 1108 and three IBM 360/30 systems.

Everyone of these changes was fully justified and controlled, as discussed previously, as a cost or expense reduction project. As I have attempted to show, computer change has made possible significant per job reductions in computation costs and provided desirable adjustments in the configuration of equipment as necessary to meet changing needs.

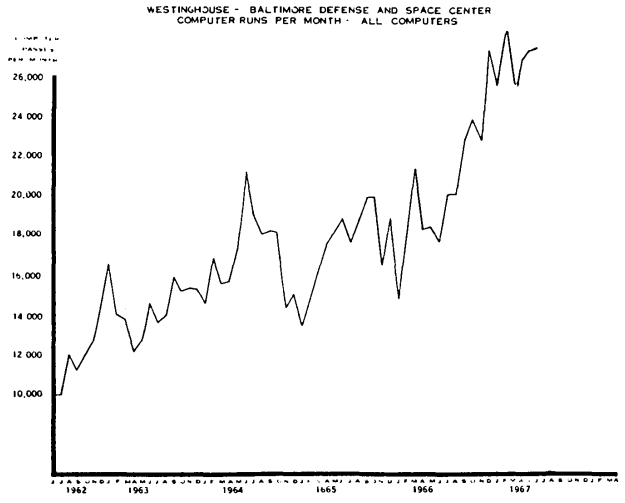


Figure 3—Westinghouse-Baltimore Defense & Space Center computer runs per month—all computers

I hope I have set the stage properly. *Computer change* should occur because newer equipment makes it possible to do the same load or an increased load at lower cost. I have tried to demonstrate that the Westinghouse-Baltimore Defense and Space Center has been able to make frequent change and has reaped the financial payoff from such change.

### *Attitude for change*

Change must be supported by the right *attitude*. Essentially the attitude which supports change seems to be common among individuals who have been connected with computers for at least five years, sometimes much longer. Many of us were using such equipment even before the prevalence of magnetic core storage. We have lived through extensive technological change. At some time in the past we may have felt "stuck" with equipment beyond its technological or economic life because of the reprogramming problem. However, we are now going to make certain that we will not be "stuck" again. During the past several years we have insisted on the use of machine independent programming languages. We have recognized that change. At some time in the past we may have felt changes in existing operating programs to meet changing requirements. In being successful, our work load has grown through the introduction of new applications. We have a record of frequent change of our rented equipment because we have long ago recognized that modular hardware existed and that equipment could grow and change to meet new requirements. Although users, we have helped to force upon the computer manufacturer some of the hardware and software im-

provements currently available. Our ideas and needs have contributed to the new generation of equipment now being made available. In summary, we "liberals" of the computing field are prepared to make rapid use of the new equipment. Change for us means an ability to get more throughput per dollar, to move into areas heretofore untouched and to help make ADP an increasingly important part of the entire organizational picture.

*State-of-the-art of program conversion*

As further background, or stage setting, for my simple "formula for change," I would like to review briefly the state-of-the-art in the area of computer system change and reprogramming.

In June, 1965, the ACM sponsored jointly with Applied Data Research, Incorporated a "Reprogramming Conference." The three-day meeting was held in Princeton, N. J., and ten of the papers presented were published in the December, 1965 issue of the Communications of the ACM. For those interested in the reprogramming problem, this issue of CACM and the many references presented is a useful starting point.

Following is a brief summary of what was said at that conference—in essence an abstract of the abstracts:

1. A large file maintenance and retrieval system was written in COBOL and run successfully on three different IBM computers (1410, 7080, and 7090).
2. Completely automatic translation of machine language programs, although highly desirable, has not been achieved. Problems are primarily of a semantic nature which can be resolved by a semi-automatic procedure.
3. A set of macro-operations was used to assist in translating from the 7090 to the 7040 by inserting this set of macros at the beginning of the 7090 symbolic deck.
4. An RCA 301 "emulation" system was used to enable 301 object programs to be run on the Spectra 70/45. The emulation concept makes use of both hardware micro-program routines and software to accomplish the required action.
5. The emulation concept was further described as it applies to running 7074, 7080 and 7090 programs on the IBM System/360.
6. A translation system was described to eliminate "most" of the effort formerly required to reprogram Philco 2000 programs for operation on the IBM 7094.
7. Techniques utilizing a meta-language to map from one assembly language into another were described. Timing problems and "perverse" use of instructions presented difficulties.
8. The 1401 compatability feature for the IBM System 360 Model 30 was discussed. This paper covered what proved to be the most widely used computer conversion aid during the past two years. As most of us know, the read only storage used on the 360/30 has made the running of 1401 programs on the 360/30 a highly successful and economical venture.
9. A variety of special translation programs have been written to aid in the translation of programs from one version of FORTRAN to another and from one computer to another. LIFT and SIFT are two such programs. CAT (Computer Aided Translation) was a CDC 3600 programming system designed to aid in the translation of IBM 7090 FAP programs into 3600 COMPASS language programs.
10. A final survey paper considered hand recoding, automatic machine language to machine language translation, decompilation, meta-assembly (a generalized assembly program that accepts as input both symbolic instructions to be assembled, and parameters that in effect specify the machine for which they are to be assembled), and computer transference.

Not included in the wrap-up paper were the techniques used to translate very similar languages (e.g., FORTRAN II to FORTRAN IV), the quasi hardware "emulator" concept for translating existing application programs (both discussed in other papers), or the very generalized UNCOL concept which requires more unanimity among computer manufacturers and users than seems achievable.

A number of computer conversions have been recently reported, e.g., Doug Williams' article in the January issue of Datamation entitled "Conversion at Lockheed Missiles and Space." Another aid in converting was reported in February Datamation by Don Herman, of Comress, Incorporated, which is now marketing TRANSIM for "translating programs" from one machine to another. This is apparently a 100% effective translation for certain selected pairs of machines.

*Management responsibility for change*

The successful Westinghouse-Baltimore approach (our formula for change) is based on a fundamental tenet of management policy, i.e., the computer facility will replace existing hardware with new improved better price performance hardware as it becomes available. Changes, as outlined previously, did take place so

computer users have come to expect change and be ready for it.

In Westinghouse-Baltimore, personnel involved in the development of information systems have been also "exposed" for some time to a Department Manual which includes an introduction that emphasizes flexibility, and I quote, "a policy of obtaining the most effective processing equipment (from a cost per unit computation point of view) and using this equipment to its maximum potential." Such a policy requires the use of programming practices which minimize the cost of conversion to new equipment, thus the necessity for so-called machine independent programming.

The Department "goal" and "responsibilities" again emphasize these points and the following statement of programming policy puts added teeth into the management emphasis.

**"FORTRAN/BEEF programming policy**

"The basic programming policy is that all programming be accomplished as described in "The Compleat Guide to FORTRAN/BEEF Programming," published by the Westinghouse Defense and Space Center. This document provides the specification of this machine independent programming approach and documents acceptable programming practices and techniques.

"The following "Statement of Programming Standards" will be rigidly adhered to:

1. FORTRAN will be used as *the* programming language for all scientific, engineering, management science and data processing applications.
2. When conventional FORTRAN statements are basically inadequate, already prepared standard subroutines (BEEF) will be used via the CALL statement.
3. If the existing subroutine library is not adequate to accomplish the required result, a new subroutine will be defined, specified, programmed, and added to the BEEF library. This new routine will be written in FORTRAN and/or the symbolic language of the computer being used. In order to maintain machine independence the new subroutine will be written for any other computer on which the program is to be run, in other words the BEEF library will be maintained.
4. As an aid in debugging new programs, the BEEF editor will be used.
5. All programs will be written so that all referenced files may be changed among tapes, card readers, drums, discs, card punches, and printers by an appropriate change of unit number.
6. Careful attention must be given to make certain that any change to a new computer, a new executive system or exploitation of major increases or decreases in hardware configuration can be accomplished without difficulty.
7. Adequate comments will be included to make certain that the intent of the program is understood by others trained in FORTRAN programming.

"You Can Be Sure If It's Westinghouse" that the present computer will be replaced by a new system in the near future."

Obviously, a management policy does not mean computer conversion is automatic. A single programming language is not the complete answer, for although the basic programming language may be the same on two computers, there are frequently operating system differences. This facet of the problem can be solved by computer editing of input decks prior to their compilation. For example, it was possible for Westinghouse-Baltimore to run IBM 7094 FORTRAN program decks, using the IBSYS control cards, directly on the UNIVAC 1107. This was accomplished by having the control cards automatically converted by the 1107 on input. A few ground rules established in 1963 provided the basis for a standard FORTRAN. The burden was placed on the new system to behave like the old. This approach to handling the minor differences in operating systems is probably in fairly common use.

A problem in computer system conversion is that the user is only being partially supported by the supplier. The supplier is willing to provide assistance in converting from a competitor's equipment to his own, but is really not interested in helping the user to become independent of all suppliers, including himself. It would appear that today's operating systems are designed to help lock you into the brand you are now using. Again, the solution is in the hands of user management who must take steps not only to establish policy as noted earlier but in following through to see that machine independence is maintained. In-house operating systems capability is a must for effective follow-through.

Another facet of the "reprogramming" problem is the fact that many of the required major information systems in wide use were written for a particular computer by the supplier, e.g., PERT/COST, or a specific Design Automation System. The supplier of the equipment probably has written the major application system in symbolic machine language and unless forced to do so the supplier of the new equipment will not readily agree to rewrite the system. Contract negotiation time is the point when such problems must be resolved. The production of generalized software to meet user specification is one area where the computer supplier will

assist, particularly if that software is of general use. Westinghouse-Baltimore has had no trouble, for example, in getting the BEEF subroutines rewritten for new equipment. McDonnell and IBM have collaborated in the rewriting of BEEF for the 360 systems. CDC has included most of the BEEF subroutines in their software support and, of course, UNIVAC maintains this package for the 1107/1108.

Another problem is getting to and maintaining computer independence in programming is the attitude of the programmer himself. Unless very carefully trained and "managed" he will not automatically adhere to computer independence concepts. Consciously or unconsciously, he doesn't want to write programs that others can understand and change or adapt to new requirements. He seems to fear being not needed on his "creation." He tries to place his own personal touch on his programs. At Westinghouse we instill in our programmers the concept that the opportunity for advancement is in a large way dependent on their ability to keep their work machine independent by careful adherence to standardized routines and by careful adequate documentation. A complete description of standard documentation procedures has been included in the Department Manual referenced earlier. If the programmer doesn't do the job in this respect, he is released or becomes relegated to the role of a clerk or maintenance programmer with little opportunity for promotion or for involvement in the development of new systems.

Computer system change should also be examined from the point of view of the level of development of the applications being run on the existing system. Briefly as we see it in Westinghouse, there are four levels of application development:

1. *Observation*—Standard data reduction or data processing, the traditional data in, processed data out approach.
2. *Predictive simulation*—First level in which the information system or the mathematical model is used for forecasting purposes; sometimes called the "what if" game.
3. *Inversion*—The problem of predictive simulation is turned around in order to achieve a "design" having a specified performance.
4. *Optimization*—At the highest level, the concern is to obtain a "best" solution from among "all" designs providing a satisfactory performance.

Computer system change in a large way depends on the application level at which an organization is currently operating; complete resystematizing and reprogramming may actually be desirable in order to provide the impetus or opportunity to move up to a higher level at the same time as hardware change.

Personnel attitude toward change and the requirements and competitiveness of the industry in which the organization functions are other major factors affecting such action.

## CONCLUSION

All of these problems, however, are overshadowed by the reductions in cost per job that computer change allows. With the right attitude, the proper management support, and proper planning, computer change can be highly successful.

I have attempted to point out that computer change is a full time continuing problem. Change to the next system must be considered even while implementing today's system change. Management policy must support *change* and all levels must work together to see that change can occur economically, quickly and effectively to satisfy the changing requirements of today's dynamic economy.