Technical Report Number CS81002-R

Acquisition of an Interactive Computing System for Academic Use: A Case Study

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January 9, 1981

ABSTRACT

The acquisition of a large-scale computer system is a complex and important task that universities face periodically. The large capital expenditures and the always expanding need for computing services ensure an increasing importance. Virginia Tech recently made such an acquisition. This paper describes the evaluation procedures leading to the acquisition, beginning with needs assessment and concluding with system selection.

The acquisition of a computing system, in this instance a system primarily for interactive instructional support of undergraduates, is a decision that is subject to a variety of influences -- technical, managerial, political, and personal. This paper describes the authors' attempts (as then Associate Director of the Computing Center and then Head of the Computer Science Department, respectively) to deal with these influences through the use of quantitative techniques, behavioral analysis, and common sense.

1.Ø INTRODUCTION

The organization of the paper is chronological. We follow the evaluation process through needs assessment, vendor discussions, the request-for-proposal (RFP) process, vendor responses and their evaluation, the evaluation of on-site visits, and the final selection. The chronology of the acquisition process is illustrated in Figure 1, which provides an overview. Throughout the paper we explain our rationale for using or ignoring potentially applicable quantitative techniques.

The applications of quantitative and behavioral methods were intended in some cases to assist in the discrimination among suggested computer systems and in other cases to recognize biases and inconsistencies among the evaluators. While our own biases are doubtlessly reflected in this paper, we have sought to identify them by the use of "commentary" sections.

The reader is reminded that the acquisition described herein applies to an interactive computer system satisfying the perceived needs of Virginia Tech in 1977 and 1978. Certain procedures, many factors, and our ultimate conclusions regarding the vendors' products would be expected to change with time and under other circumstances. Hence, the systems referred to herein are in no way endorsed nor recommended by the authors over those of other vendors for any other acquisition.

2.Ø NEEDS ASSESSMENT

Prior to the proposal for an interactive laboratory, groups within the user community had criticized the computing services supporting teaching and research. Consequently, the Computing Center and the academic user community were asked jointly to select equipment for an interactive

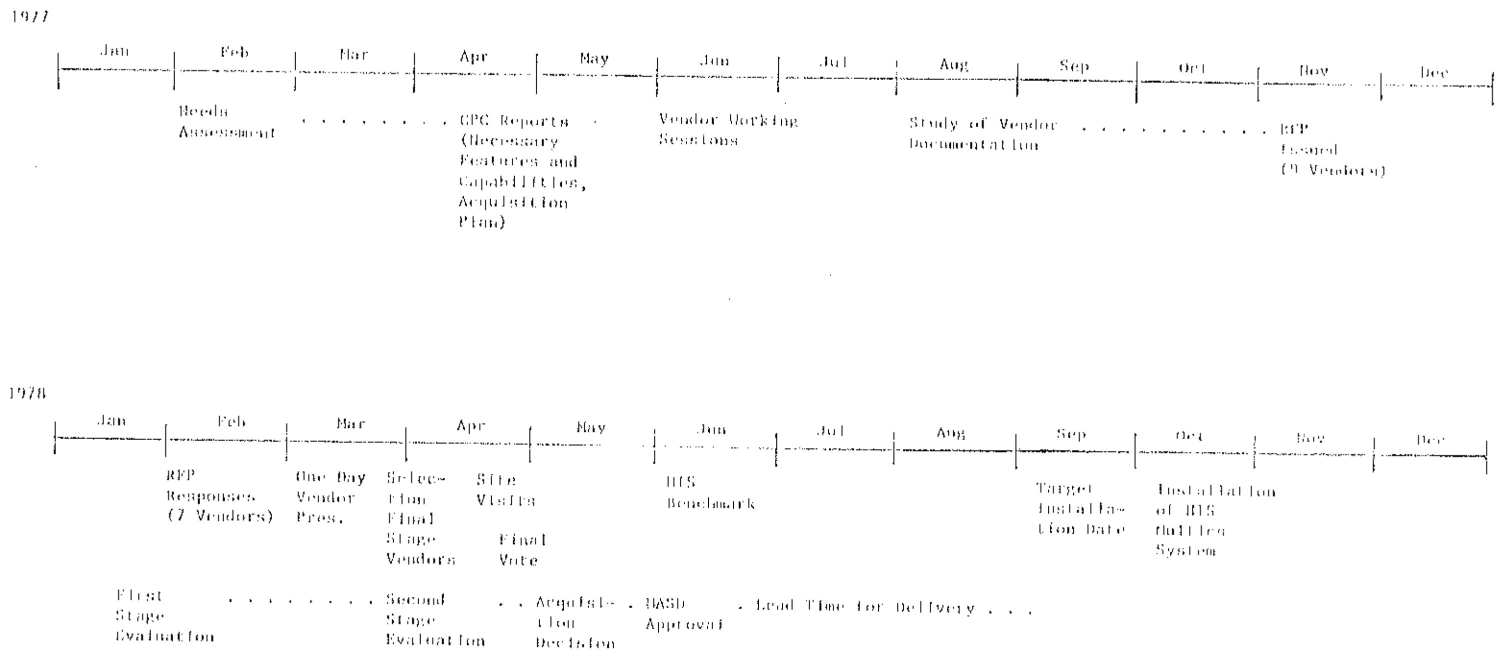

Figure 1. The Chronology of the Acquisition Process

laboratory. In an environment of some discontent, an attempt at a proposed joint Computing Center/academic user acquisition decision seemed fraught with risk. The authors recognized that objective appraisal could easily be overruled by personal prejudices and self-serving motivations. Thus, quantitative techniques were viewed as a control on such temptations as well as an assistance in the evaluation work. The use of behavioral analysis (to supplement quantitative methods) would provide a monitor, a posteriori, on the evaluation procedures.

2.1 The Assessment Strategy

The joint acquisition process (involving the Computing Center, the Computer Science Department, and interested campus "at large" groups) began in February 1977 with a study to determine the instructional and research needs for interactive computing service. The assessment plan of the joint study group called for the development of a list of useful features from among those available on modern interactive system. The features list was constructed through input from within and outside the University. A team from the Computing Center then worked with potential campus users to: 1) describe the utility of features and obtain a quantified assessment of them, and 2) acquire a description of potential applications with each quantified according to capabilities, limitations, and sizing requirements. From this assessment a service model was constructed. The major steps of needs assessment were to:

1. Develop features by experts and educators,
2. Discuss features with potential users,
3. Quantify users' responses, and
4. Construct the service model.

The service feature set was developed through the use of systems analysis techniques [QUAE 68]. Systems analysis removed two difficulties: the large number of choices involved and the lack of a theoretical foundation for the decision-making. Systems analysis involved investigating the complete service problem, identifying objectives and alternatives, and comparing and contrasting them in terms of their consequences. From the features list a service model was constructed through expert judgement, survey research, statistical analysis, and intuition. The features list (for the model) was compiled by expert users of candidate systems and by educators who could identify instructional and research service needs. Tables 1-3 show some features and a portion of the service model. The Delphi Method [DALN 69], frequently used to advantage in seeking consensus, was not employed to construct the features list because some contributors were not resident at the University and the timely feedback of information would have been difficult to obtain. Hence, the list became the union of all suggested features rather than a set mutually agreed upon. A recent methodological development by Mamrak and Amer [MAMR 79] would have been welcomed.

Transparency	Open-ended	Directory
Directory Access	Multiple Users	File Protect
System Access	Automatic Archive	Explicit Archive
Retrieval	Archive Directory	Exemption
Filename	File Versions	File Maintenance
File Abbreviation	Restoration	

Table 1 - Kinds of file system features

Argument Prompting	Intracommand Help	Abbreviation
Character Editing	Line Editing	Field Editing
Full Duplex	Line Buffering	Psuedo Interrupts
Interprocess Comm.	Multiple Jobs	Linking
Consulting	User Debugging	Interactive Jobs
Job Status	Accounting Info.	Access Controls
Scheduler	System Debugging	Message Processing
Network Protocols	Type Ahead	

Table 2 - Kinds of programming and terminal features

APPLICATIONS:

Instructional Categories of Use:
- Problem Solving
- Database Manipulation
- Computer Aided Instruction
- Computer Aided Design
- Syntax Analysis of Programming Languages
- Text Processing and Content Analysis
- Use of Production Programs
- Interactive Graphics

Research Categories of Use:
- Simulation and Modeling
- Database Management
- Syntax Checking of User-oriented Languages
- Computer Systems Development
- Systems Performance Evaluation
- High Quality Manuscript Preparation
- Use of Special Packages
- Interactive Graphics

SOFTWARE SUPPORT:

Language Processors
Editors
Computer Aided Instruction Programs

Table 3 - Elements of the service model

Concurrent with developing the features list, the joint needs study group contacted potential user groups to arrange structured interviews [BABE 73]. An interview team chose the academic groups (sixty in number) whose computing budget exceeded $5,000 annually. Of the sixty groups contacted, forty groups (comprised of departments, laboratories, centers, and divisions) responded and were interviewed in detail to gain an understanding of their present uses, desired but unmet needs, and planned future applications. Structured interviews aided the explanation of prominent features of modern interactive computing systems by allowing the interviewer to:

1. Probe to decrease the number of "don't knows,"
2. Clarify ambiguities to improve the relevancy of responses, and
3. Observe as well as ask questions.

Data gathering (the interview process), data reduction, and analysis were conducted by the Computing Center. Evaluation of these findings led to recommendations by the joint needs study group. Recommendations were submitted to the Computer Policy Committee (CPC) [an advisory committee to the President, chaired by the Vice President for Administration, to whom the Computing Center reports administratively] in April and May of 1977, as CPC reports. The reports contained the composite opinion of those interviewed. In particular, they described specific features and capabilities that were rated necessary and/or desirable by the potential users.

2.2 A Quantitative Evaluation of Features

A total of about 200 faculty were interviewed in the different group interviews. Important service features of interactive systems were described in each interview. The participants rated the utility of each feature, according to their perceived needs, on the following numerical scale.

1. Not desirable and not useful.
2. Desirable, but questionable utility.
3. Desirable and limited utility.
4. Desirable and useful.
5. Highly desirable and useful.
6. Highly desirable and highly useful.
7. Absolute requirement.

The scale was treated as an interval scale [GILJ 73] for purposes of computation and analysis. For each feature achieving a composite weighted rating exceeding a predetermined threshold, the following information was included in the CPC reports:

1. A brief description of the feature,
2. The highest rating it received,
3. The rating most frequently given (the mode),
4. The arithmetic average of responses, and
5. A measure of the variability of responses.

Table 5 provides an example feature description with accompanying statistics.

PROTECTION/ACCESS MECHANISM

Description: The following attributes comprise the access/protection mechanism.

1. Each user has a directory which may contain an arbitrary number of files.

2. Directories are accessed by user identification, password, and account number.

3. Multiple users per account are permitted.

4. Read and write access privileges may be assigned via a single instruction to individual files within a directory. Users may set their own default protection.

5. Users may access subsystem and other user programs of more widespread (than their department's) use.

Highest Rating:	7
Mode:	7
Mean:	6.3
Standard Deviation:	Ø.8

Table 4 - Example feature description

2.3 System Sizing

The CPC reports addressed applications, system sizing, and terminal configurations/distributions. Highly significant was the conclusion that the planned system, because of budgetary constraints, would fall far short of satisfying the complete instructional needs. Sizing requirements were examined along four axes: 1) the number of student-quarter-hours per year, 2) terminal access requirements, 3) file storage requirements, and 4) proposed annual expenditures for interactive computing. In each of these four dimensions the stated need greatly exceeded the budgeted system. Tables 5-8 summarize these sizing requirement findings.

Department	Student-quarters per year
1-23	15,523 total

Legend: With enrollment at about 20,000 students, about three of four students enrolled would be exposed to one quarter per year of interactive computer instruction, on an average.

Table 5 - System sizing by student-quarters per year

TERMINAL INFORMATION CATEGORIES:

Number needed for classroom use
Types and features
Line speeds
Special remote peripheral equipment
Terminal locations

RECOMMENDATIONS:

Optimum class size 12-20; 3 classrooms
All upper/lower case shifts
Some APL features, local hardcopy, graphics, large screen size, hardwired and dial-up
1200-2400 baud for text; 4800-9600 for graphics
Fast printer and RJE facility
Minimum distance: classroom to department building
Large mixed present terminal inventory useful

Table 6 - System sizing by terminal requirements

SIZES:

Needs approach one billion bytes
Budgeted system: 500 million bytes

RECOMMENDATIONS:

Workable archival system
Appropriate secondary storage pricing incentives

Table 7 - System sizing by file storage requirements

BASIS:

36 departments responding
20-100 percent of individual department budgets to be spent on interactive computing

RESULT:

First year's expenditures would be approximately equal to the purchase price of mainframe and peripherals.

Table 8 - System sizing by projected expenditures

The CPC reports proposed a multi-step plan for assessing and obtaining those facilities deemed necessary for present and near-term future academic use. As a first step, an interactive environment on a medium scale was to be implemented. Such a system would permit academic users to explore in depth their actual (not perceived) costs and benefits. Experience with this interactive environment would provide the proper foundation for defining the succeeding steps over a projected five year development period. Four recommendations accompanied the multi-step plan.

1. A complete configuration should be obtained from the outset, including terminals and communication equipment.
2. Three campus locations were suggested for four classrooms based upon a population-density-of-use study, see Table 1.
3. Performance and costs should be measured so that users could realistically evaluate the benefits of the new system. Performance measures, not usage statistics, were advised.
4. No priority use of the system would be permitted since the guarantee of relatively constant access and response times (accomplished by "pie-slicing") enables users to plan and use their computing time more efficiently, see Table 2.

2.4 Commentary

The CPC reports accomplished three objectives.

1. They substantiated claims of the size of the unmet needs cited earlier by the academic community.
2. Those interviewed were able to compare their interactive computing needs with those of other users.
3. The selected service features constituted a "shopping list" useful in assessing vendors' systems.

The changing nature of the University's computing needs, particularly for interactive support, had been investigated and documented earlier. Thus the CPC reports did not belabor the need, rather, they identified specific requirements and proposed a general solution. They also substantiated several conclusions.

First, an imbalance existed between interactive computing and batch (on- and off-line) processing services. Interviewed departments expressed expectations of reallocating from 20 percent to as much as 100 percent of their computing budgets to interactive computing as opposed to batch.

Second, the combination of instructional and research needs would enable the acquisition of a facility more capable of meeting the quantity and diversity of demand than would be possible if only instructional needs were considered.

Third, the lack of interactive computing use by undergraduates was viewed as a critical deficiency. Faculty in some departments related the disdain expressed by cooperative education students, who found the transition from interactive support in their work environment to the batch use most distasteful.

Fourth, many users of the University's existing online system were sharply critical of its shortcomings in human design and of its limited capabilities. While serving adequately as a software development tool, many academic users felt it to be unsupportive of computer augmented instruction, interactive demonstration, and empirical investigation akin to the use of a science laboratory.

3.Ø PRELIMINARY DISCUSSIONS WITH VENDORS

3.1 Vendor Working Sessions

After the CPC reports were completed, the joint study team conducted working sessions with leading vendors. The purpose was twofold: to investigate tentative system configurations and to assess the likelihood that available systems, within the designated budgetary limitation, could meet the expressed needs. The meeting format was carefully controlled so that each vendor was asked to respond to the same questions, which covered the needed system features produced from the earlier user interviews.

3.2 Vendor Rankings

Following these sessions, and after subsequently studying vendor documentation, the study team rated the systems in terms of agreement with the expressed needs. Honeywell Information Systems (HIS) and Digital Equipment Corporation (DEC) achieved the highest rankings. Kendall's coefficient of concordance (Ø,w,1) [DOWN 74] was computed to determine the overall relationship among the ratings of the judges. A value of w=Ø.39 indicated agreement at the Ø.Ø1 level. The acquired data gave a computed value of w=Ø.9Ø, see Table 3. Thus the HIS and DEC systems were judged to meet our objectives much better than the systems of other vendors.

3.3 Commentary

Three general observations emerged from the working sessions.

1. Little cross-fertilization of ideas and practices among the vendors was observed. With exceptions, vendors contrasted their most recent time-sharing system with their earlier efforts. Yet, they lacked awareness of current competitive offerings and of the important extensions to competitive offerings which had been developed by and were available from universities and research institutions.
2. Systems proposed by the vendors could provide a large number of the desired features. No vendor should be excluded from responding to an RFP based upon information provided by these sessions.
3. Systems offered by DEC and HIS most nearly provided the desired features. In particular these systems appeared extremely simple for novice users, with the smooth and easy transition from novice to expert being facilitated by, as one potential user put it, "the seven veils approach".

4.Ø THE REQUEST-FOR-PROPOSAL

The CPC reports were unanimously endorsed by the Computer Policy Committee which agreed to the acquisition of an interactive instructional system by September 15, 1978 (the beginning of the academic year). The subsequent RFP was faithful in characterizing the needs arising from the

February 1977 interviews. The RFP defined a problem, unlike many such requests which constrain the configuration so tightly as to virtually specify a solution, hence preventing some capable vendors from even replying. Generally, vendors shared our perceptions of the RFP.

The benchmark section of the RFP closely resembled a suitable procedure for online batch. Our aim in benchmarking was merely to uncover gross inefficiencies in performance. We intended to rely on special tests and site visits for information on performance and capabilities.

In November 1977, the RFP was issued to nine vendors. Questions of general interest submitted by vendors together with our responses were distributed to all vendors. The bidder's conference was held in December 1977.

5.Ø THE PROPOSAL EVALUATION PROCESS

5.1 Evaluation of the RFP Response

Bids were received in February 1978 from seven of nine vendors to which the RFP was sent. The evaluation was conducted in two phases. The initial evaluation sought to reduce the field of vendors to the two or three most promising ones, based on proposal evaluations, vendors' oral presentations, and brief experimentation with each system. (The more intensive study of remaining vendors is covered in the next section of this paper.) Three groups were established to conduct the initial evaluation: 1) a volunteer group representing the campus-at-large, 2) a volunteer group representing the Computer Science Department, including student representation, and 3) a group appointed within the Computing Center. Other specific individuals within the Center were tasked to provide information on operational characteristics, hardware and maintenance, costs and contracts, training and documentation, the user's viewpoint, and a system perspective.

Each of the three groups (Center, Computer Science, and campus-at-large) were given the proposals and accompanying documentation. The groups formulated and submitted written questions to vendors requesting clarification where bids were vague or incomplete.

5.2 Oral Presentations to Augment the RFP Response

One-day oral presentations by vendors were then scheduled. Unlike the working sessions with vendors in early 1977, the format and content of these presentations were decided by the vendors. The limited scope of the earlier sessions was aimed at determining to what extent vendors could comply with our model, within explicit dollar limits. In the 1978 presentations, vendors were to describe their proposed systems, including any features deemed useful for our purposes that were not explicitly required in the RFP. Presentations were open and were marked by much interaction among Virginia Tech personnel and vendors. Often important new issues were introduced and resolved.

Two vendors chose to bring terminals and provide live demonstrations via dial-up to their home systems. This added appreciably to their system's auhenticity and to the audience's reception. Because of the value of these demonstrations and because some disturbing questions remained regarding usability, systems completeness, and consistency, each vendor was asked to provide several hours of connect time for a configuration running their proposed operating system. Using this time, Computing Center personnel further explored the systems, and reported findings to the three groups.

5.3 Summary of the First Stage Evaluation

In summary, the first stage evaluation was conducted by three teams: a volunteer group representing the campus-at-large, a volunteer group from the Computer Science Department, and an appointed group from the Computing Center. Each group utilized different evaluation procedures. The campus-at-large group worked as independent assessors; the Computing Center group utilized a Commonwealth of Virginia point system; and the Computer Science Department, a dual level scheme which distinguished features deemed useful for the novice from the extended features appealing to the advanced user.

The written evaluations by each team included a brief description of the evaluation process and a brief reaction to each proposed system. Each team concluded with an explicit list of those systems which deserved further consideration.

For various reasons, certain individuals preferred to conduct their own evaluations outside the team deliberations. While not discouraged from pursuing this tact, these individuals were given no assurances as to how their recommendations would be treated. However, an expressed intent to give consideration to all opinions reflected the openness of the process.

5.4 Commentary

Evaluation results and recommendations were very consistent across the teams and other individuals. The three teams recommended further consideration of HIS (Multics) and DEC (TOPS-2Ø). One individual's report recommended these two systems along with a third vendor. A minority of the Center team recommended yet another vendor (in addition to HIS and DEC) on a nontechnical basis. In terms of aggregate point totals HIS was far in the lead at the end of the first stage of evaluation. DEC was a distant second, but far above the others, which were clustered.

Given such recommendations, how should the evaluation proceed? The following suggestions were proposed.

1. Take the intersection, i.e., HIS and DEC, for further study. The rationale being that all evaluators agree on these two systems. Also, the two remaining systems could be studied more comprehensively. An objection to this suggestion was based on the omission of two vendors whom a total of four of 23 evaluators felt should be included.
2. Take the union. The rationale here is the complement of the above, i.e., consider any system anyone believes can do the job.
3. Invite those people recommending systems outside the intersection to explicate their technical justification, then act on this information.
4. Allow the Computing Center to choose.
5. Ask the Computer Policy Committee to decide.

Faculty generally looked upon the latter two suggestions with disfavor.

A suggested resolution to the problem involved the calculation of some simple statistics on the evaluation data and support them with a logical argument for the intersection. However, this approach seemed unlikely to convince those four people proposing another system. Yet, if the union were chosen, then should not all systems be included that were ranked above any in the union by any other of the evaluators? When this criterion is applied no vendors are eliminated. The inclusion of a third systems includes another complication since all agreed that HIS and DEC are viable and rank one and two, and most felt that the other systems were not viable. How then would one ever expect to later get consensus on a third system?

The Vice-President for Administration (chairing the Computer Policy Committee) resolved the dilemma by directing the evaluation to proceed with DEC and HIS.

6.Ø FINAL EVALUATION AND VENDOR SELECTION

6.1 Comprehensive Special Tests

The schedule for comprehensive special tests was announced in March 1978. The purpose of these tests was to explore, in depth, ease of use and functional capability. Tests were conducted online from Virginia Tech using HIS's host system in Phoenix and DEC's host system in Marlboro. The composition of evaluation teams differed from the organizationally related structure of the first stage evaluation. Four teams were established, each containing members from the campus-at-large group, the Computer Science Department, and the Computing Center. Different exercises were assigned to three hetergeneous teams conducting the second stage evaluation.

Each team received a procedures manual containing two sets of exercises. Each team performed and rated 'primary' exercises. Also, each team performed and rated one (unique) set of 'secondary' exercises. They then tested and rated the two systems in any other desirable ways, designated them as 'custom' exercises.

Primary and secondary exercises were distinguished because time did not permit each team to perform all exercises. Yet, it was important to test each feature identified in the RFP. Features most useful to the majority of users appeared in the primary set. Features such as scheduler tuning and archival operations, which require privileged access or installation parameter modification, were excluded from special tests. Such features were investigated via discussions with installations during site visits.

Written evaluation reports with numerical scoring were completed by the four teams in April 1978. Although teams performed the exercises as units, each invididual provided separate ratings, comments, and explanations. Finally, each individual submitted one vote for the system of his/her choice. An individual's final vote was predicated upon everything he/she knew about the systems; thus final votes were not required to correspond to the numerical ratings.

During final evaluation, a performance test was also conducted by the Computing Center on both systems, as bid. The purpose of the tests was to locate blatant deficiencies, if any. Programs, selected from a benchmark set based upon earlier interview data, included I/O-bound jobs, CPU-bound jobs, and jobs to create paging activity. Tests were run on unloaded systems. The power of the tests was not sufficient to make performance comparisons between the systems under anticipated usage conditions. While running the programs, live online terminal exercises were conducted and their response times noted. Using the configurations bid at that time, the DEC system out-performed the HIS system. We concluded that both systems, as bid at that time, performed approximately as expected.

6.2 The Voting Process

Votes for systems were submitted in April 1978. The vote favored Multics over TOPS-20 by about two to one. This tally is somewhat misleading in that all but one of the faculty and students (i.e., the users) indicated that their decision was very close and that either system would adequately fulfill the stated objectives. The Computing Center personnel (i.e., the service providers) favored Multics by four to one and were much more adamant. While TOPS-20 was a three to one choice by the Computer Science Department, they expressed the opinion that Multics was an acceptable alternative.

6.3 Commentary on the Voting Outcome

That (most users found either system acceptable is interesting since HIS had such a commanding lead over DEC at the completion of the first phase of the evaluation. The performance difference did not substantially contribute to decision making because this difference was overcome by HIS in their best and final offer. Given the different financial arrangements for the two systems, the price differential proved insignificant.

The advantages of TOPS-20 most often cited were: 1) terminal input with recognition, completion, abbreviation method, and control characters was a superior concept, 2) the large number of TOPS-20 and TENEX installations at other universities and research institutions would result in more exchange of work, and 3) DEC's future directions and company commitment to TOPS-20 were felt to be sounder. The strongest and most commonly cited advantages of HIS were that Multics was more complete and more consistent in its behavior. Particularly, its administrative structure and security controls lent themselves very nicely to our academic environment. The perceived advantages of each operating system are summarized below.

TOPS-2Ø:
Superior terminal interaction,
Broad university base throughout the country, and
Strong DEC commitment to TOPS-2Ø.

Multics:
Completeness and consistency, and
Administrative structure and controls.

6.4 Site Visits

In April 1978 groups visited Massachusetts Intitute of Technology and Southwestern Louisiana (Multics installations) and Carnegie-Mellon and Stanford (TOPS-2Ø installations). A guideline was used in acquiring consistent and useful information from each site. It included questions in the following categories.

1. Services provided,
2. Configuration of system,
3. Software availability,
4. Problems and prospects for providing undergraduate instruction,
5. Education, documentation, consulting and user groups,
6. Vendor rapport,
7. Tasks found difficult to accomplish with the system, and
8. Operations.

Upon return, findings were prepared for the evaluators.

6.5 Vendor Selection and Commonwealth Approval

DEC and HIS were notified in April 1978 of Virginia Tech's acceptance of the HIS best and final proposal. Accordingly, a formal request for approval was submitted to the Office for Management and Systems Development (MASD) of the Commonwealth for the required endorsements.

Virginia Tech's work with MASD on the interactive system evaluation and procurement proceeded smoothly and without major setback. The inclusion of the procurement in earlier budget submissions and the involvement of MASD throughout the procurement contributed to the prompt approval.

6.6 Benchmarking

At faculty request (and as a condition of final acceptance) the selected system was benchmarked in more depth than the earlier performance check allowed [NBS 77]. The HIS system was benchmarked in Phoenix during June 1978. The test specified a distribution function of acceptable response times for commands defined as trivial and a similar one for nontrivial computations. The benchmark characteristics can be summarized as follows.

Background batch:
- CPU-bound jobs,
- I/O-bound jobs, and
- Page thrashing jobs.

Outline activity:
- Simulated terminals running scripts, and
- Live terminals measuring trivial and nontrivial operations.

Tests were completed satisfactorily. The identical benchmark was successfully repeated upon installation of the equipment in September 1978.

7.Ø BEHAVIORAL ISSUES

The application of quantitative techniques, alone, to the acquisition of data processing equipment does not ensure a successful procurement. Behavioral issues in small groups [MADT 69] are equally important in determining opinions and influencing outcomes. Group interactions can be measured to quantitatively answer such questions as: "What is the relationship between the size of the group and its task performance?" During this procurement, several attributes vis a vis group interaction were considered. As an illustration, the results of a post hoc test instrument are briefly described below.

During initial evaluation, group composition was homogeneous -- the Computing Center, the Computer Science Department, and the campus-at-large groups. After studying the decisions reported during this evaluation, we felt that a common set of objectives for the system were not necessarily shared across the homogeneous groups, even though each participant was asked to carefully study the CPC reports and the RFP. Intuition led us to believe that, due to the homogeneity within groups and possible differences among groups, individuals analyzed systems from a limited perspective not shared by members of other groups. To eliminate these assumed shortcomings, a heterogeneous group structure was adopted for the second stage (final) evaluation. Each second stage team included members of each of the original three groups. It was hoped that this amalgamation would promote mutual understanding and result in a broader, as well as, more indepth, analysis.

What were the differences between the uniform and nonuniform organizations? And how did these differences impact the evaluation outcome? We were not able to answer these questions definitively. However, some insights were acquired by submitting to some of the participants a questionnaire which dealt with behavioral properties of the groups [HEMJ 56].

The participants described both groups in which they had worked in their answers to 15Ø questions. Specifically, the questions related to 13 somewhat independent variables describing the two groups. Perceptions of the groups' effects with respect to these attributes are given below. The word 'significant' below should be interpreted such that at the Ø.Ø5 level their perceptions would be shared by others under the same conditions. However, one should not draw firm conclusions from these results, given the very small sample size.

1. Autonomy - Both structures enjoyed a moderate amount of autonomy, with no significant difference between homogeneous and heterogeneous group organizations.
2. Control - In general, a low degree of regulation of individuals by the group was reported. The Computer Science participants did feel that significantly more control was exercised over individuals in their homogeneous group.
3. Flexibility - A high degree of flexibility was witnessed in both structures. The Computing Center participants felt that significantly more informal procedures were used in the heterogeneous groups.
4. Hedonic Tone - There was a high degree of agreement and pleasantness in all groups. The Computer Science participants noted significantly more in their homogeneous group.
5. Homogeneity - A moderate amount of uniformity was reported with respect to the two structures, with no differences between them.
6. Intimacy - The Computing Center and Computer Science participants felt that much more familiarity was evident in the homogeneous

organizations. The campus-at-large people felt just the opposite. (The first two groups' opinions fit our intuitive notion. The campus-at-large group, made up of previously unacquainted members, worked more as individuals than as a team in the first stage evaluation.)

7. Participation - Members applied a moderate amount of their time to the group activities. No significant time difference between structures was perceived. However, the Computer Science participants felt they spent significantly more time spent on the endeavor than did the Computing Center personnel. (Note that the Computer Science faculty participants were not relieved of teaching or other duties during the evaluation, which explains their perceptions.)

8. Permeability - All participants felt that additional membership was neither sought nor denied.

9. Polarization - All participants felt that they were working as a group toward a common objective. No differences were noted with respect to structure.

10. Potency - An average amount of control with regard to adjusting group membership was noted. The single exception was that the Computer Science participants felt that the heterogeneous groups in which they participated had less authority to regulate membership.

11. Stability - All groups maintained their nature, objectives, and characteristics throughout the exercise.

12. Stratification - Generally, there was a low degree of status hierarchies across all groups. Yet, significantly more

stratification and differential behavior was perceived among members of the Computing Center and Computer Science homogeneous groups as compared to heterogeneous groups in which their members participated.

13. Viscidity - All groups functioned as single units with little or no dissention nor personal conflicts.

Evidently, the heterogeneous arrangement offers slight advantages in that it reduces stratification and control while enhancing flexibility. However, our earlier assumption that the heterogeneous discipline would provide significant advantages is apparently unfounded with respect to the variables measured. Consequently, we see no clear advantage to either organization, given the earlier caveat concerning sample size.

In this illustration, we specifically choose a counterintuitive example. We believe that it is very important to the project's results to ascertain where real differences do exist, and then to organize and conduct the procurement on the basis of this knowledge. Many such considerations arise. We leave the reader with another such example question. Are there significant differences between the formats chosen for vendor presentations in 1977 and those used in 1978?

8.Ø CONCLUDING THOUGHT

No practical procedures are known to ensure complete objectivity in the analysis and evaluation of ADP systems. The administrative/academic dichotomy of universities often tends to polarize opinions, further lessening objectivity. Although the procurement participants generally expressed little faith in exact numerical values resulting from statistical calculations, they generally felt that those values obtained through quantitative measures were basically sound, tended to reduce biases, and supported subjective conclusions. The techniques and procedures described herein are not offered as applicable and necessary for all procurement decisions. However, we have concluded that analytical methods and behavioral measures help to reduce the biases and unsubstantial opinions that always influence the eventual outcome.

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