REPORT NO. DOT-TSC-OST-72-26

# TRANSPORTATION ANALYSIS AND SIMULATION SYSTEM REQUIREMENTS

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APRIL 1973

PRELIMINARY MEMORANDUM

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16. Abstract

This document provides:

a. A brief summary of overall project (PPA OS223) accomplishments during FY 72.

b. A detailed summary of the following two major FY 72 activities:

   1. Analysis of TSC's computational resources and their utilization;

   2. Projection of TSC's FY 77 computational system demands.

Section 1 provides an overview of the project, including reasons for the project, its objectives and history, and the status at the close of FY 72. Section 2 presents the growth strategy of TSC and the projected scope of program activity in FY 77. Section 3 addresses the present TSC computer system resources and their utilization. Section 4 describes the methodology used to project FY 77 computer system demands and presents the results of the projection process.

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# PREFACE

The purpose of this report is to serve as an internal TSC milestone document reflecting the activity and status of the Transportation Analysis and Simulation System (TASS) project at the end of FY72. The project was planned and conducted by the TASF Program Office, Transportation Systems Development Directorate, Transportation Systems Center. The project was sponsored by the Office of R&D Policy, Office of the Assistant Secretary for Systems Development and Technology, Office of the Secretary.

The major external contribution to the project effort was a study directed by Professor Joseph Sussman of the Massachusetts Institute of Technology, Department of Civil Engineering, under Contract to the Transportation Systems Center. The objective of the study was to make a first-order projection of the magnitude and nature of the computer system needs of the TSC in FY77.

The MIT computer requirements projection was based on TSC's growth strategy as defined by TSC during the latter part of FY72. Since the completion of the study TSC's goals and objectives have changed significantly. TSC is increasing its emphasis on the socio-economic aspects of transportation planning and the center has been designated as the focal point in DOT for transportation technology sharing with state and local governments. Also, the TSC funding growth rate is significantly less than was input to the analysis. Consequently, the results of the study, though only reflecting a first-order analysis, are not consistent with the new direction of TSC. However, the results of the MIT study can be useful as a reference from which to view the impact of the new direction. The increase in emphasis to the "soft" sciences should tend to increase the average computer resources required per project which the decrease in TSC funding expectations should tend to decrease the total computer resources required. The increasing emphasis on socio-economics and role of technology sharing should tend to increase the need for accessability to large data bases and transportation programs throughout the United States.

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# 1.0 INTRODUCTION

## 1.1 SCOPE OF DOCUMENT

This document provides:

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## 1.2 BACKGROUND

### 1.2.1 Need for Study

As the transportation costs of the United States are steadily increasing, the solution to the transportation problems are becoming substantially larger in scope and more difficult to comprehend. Transportation programs involve so many interdependent variables that the solutions to transportation planning often defy intuition. For example, investment in highways affects land utilization, railroad and airline demand, pollution, population movement, and other socio-economic conditions which in turn all affect highway demand. The approach to transportation planning is progressively moving toward integrated analysis involving as many interrelated variables as feasible. The difficulties of analysis are compounded by the lack of computer system tools specifically designed to accommodate a systematic approach to the solution of large transportation problems.

Based on the growth strategy of the Transportation Systems Center (TSC), it is estimated that by 1977 the budget will be approximately $152 million/year and that approximately $44 million will be direct in-house expenditures. Since this increased workload is being directed toward larger and more complex transportation programs, in the future TSC will require access to a large computational system with software and hardware features specifically designed to provide a systematic approach to the solution of transportation problems. Soon after its formation, TSC recognized the potential need for an improved computational system and initiated a study effort in this area.

### 1.2.2 Overall Project Objectives

The project objectives are to determine and to define the computational system resources that TSC will require by FY 77, to provide a plan on how best to acquire the required additional computational resources, and to design and implement a new system if the present system cannot satisfactorily meet the TSC's growth needs through normal expansion.

The year FY 77 was selected as the requirements projection year, because it is estimated that any totally new system cannot be designed and implemented before FY 77 and because TSC's growth strategy shows that the major portion of TSC's growth will be completed by FY 77.

### 1.2.3 Project History

From August 1970 through June 1971 the concept of a Transportation Analysis and Simulation Facility (TASF) was in an exploratory and initial planning phase. Preliminary work was performed on developing an approach to the definition and implementation of the facility.

At the close of FY71, it was decided that FY72 activity should focus on the definition and development of one aspect of a conceptual TASF. A project (PPA OS216) was initiated with the objective of defining an interactive system for transportation planning and analysis.

In November 1971, it was decided that the design and implementation of the total TASF system should begin. PPA OS216 was closed and PPA OS223 was initiated. The initial objective for FY72 was to perform a generic design study and tasks were defined to support this objective. However, in January 1972, a project re-evaluation resulted in a change in direction. The following new objectives were established:

a. To define TSC's computer system needs.

b. To define options to meet these needs and select the most promising.

This new direction called for a more lengthy and systematic analysis to provide a more comprehensive justification for implementing a new TSC system. The new direction also deleted consideration of a special building for housing the system. Hence, the terminology for the system was changed to Transportation Analysis and Simulation System (TASS).

## 1.3 TASK APPROACH

This report addresses the approach which has been followed since the redefinition of FY 72 objectives in January 1972. The overall approach is:

a. To determine a first-order approximation of TSC's FY 77 computational system demands;

b. To determine the capabilities and utilization of TSC's present computer resources;

c. If the present facilities are not adequate, to perform a cost/benefit analysis of viable system growth options which will satisfy the computational system demands.

Tasks were reoriented to meet the new objectives. Two system studies initiated under the previous approach were continued because they were commensurate with the preliminary study phase of the project. The task flow is illustrated in block diagram format in Figure 1-1. The task functions are briefly described below.

### 1.3.1 TSC Resource/Utilization Study

A TSC computer resource survey and analysis defines TSC's system capabilities and how the systems serve the computational support TSC's programs require. Possible shortcomings to be overcome in future systems are determined.

### 1.3.2 FY 77 Program Projection

To determine the computational system needs of TSC in FY 77, it is essential to project the nature of TSC in FY 77. This requires that TSC's growth strategy be analyzed to delineate program data parameters (program characteristics and budget) which impact computational system demands.

### 1.3.3 FY 77 Computational System Demands

The program data parameters delineated in the program projection serve as input to a computational system demand projection process. The process, performed under contract by the Massachusetts Institute of Technology (MIT) in conjunction with TSC, comprises the following steps:

a. A study of computer utilization in a spectrum of previous transportation projects performed by experienced consultant contractors;

b. A study of the computer system needs of different users involved in transportation programs;

c. Utilization of a first-order projection methodology (which factors in the above two steps) to determine qualitative and quantitative computer system demand parameters.

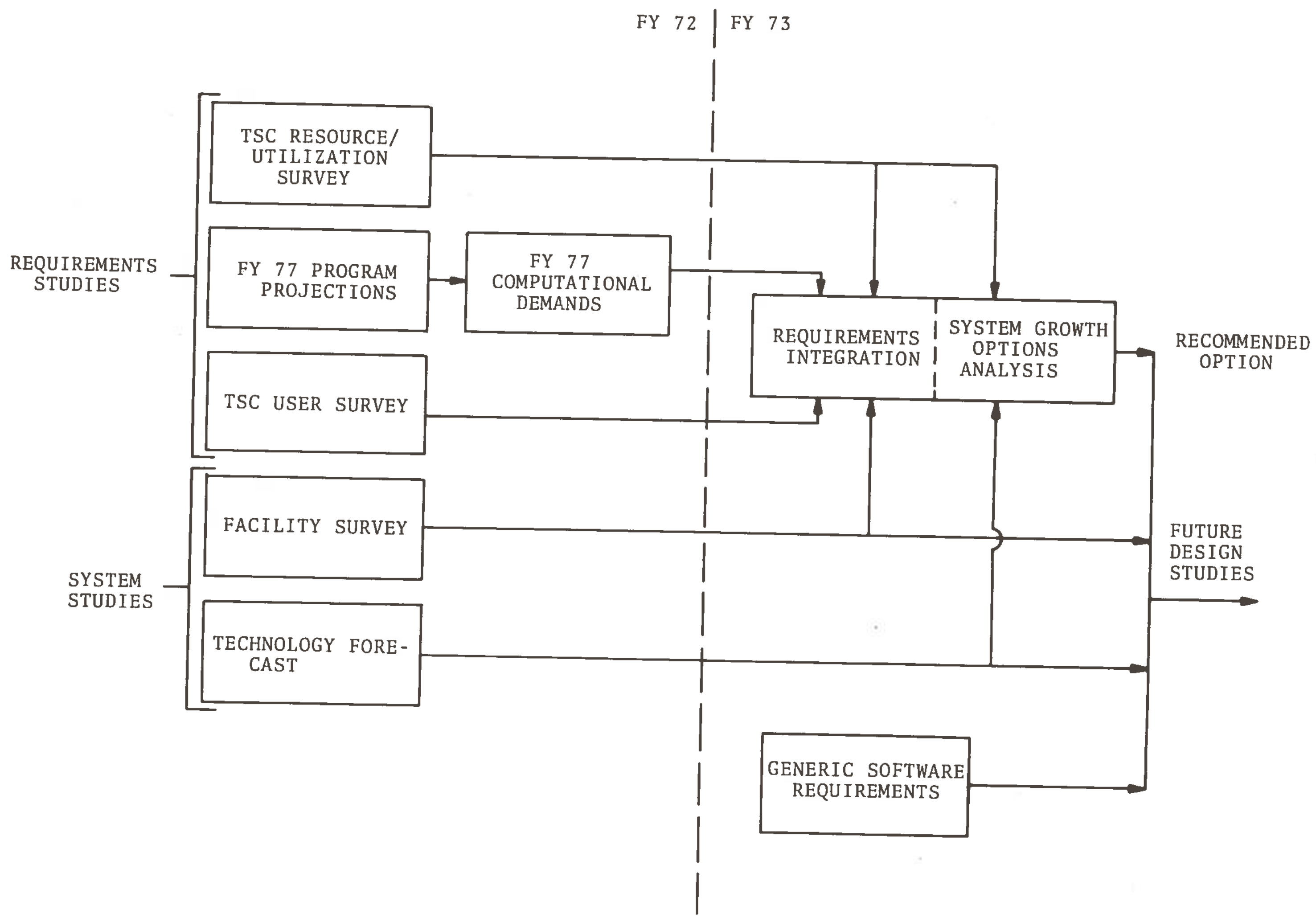



Figure 1-1 Task Approach

### 1.3.4 TSC User Requirements Survey

Quick, rough estimates of future computational resources requirements are obtained from TSC division chiefs. The survey is not intended to provide a detailed estimate on future needs but to indicate trends and to serve as a cross check for needs that might be missed using the projection methodology. The survey also serves to involve users in the planning process.

### 1.3.5 System Growth Options

The spectrum of requirements are finalized and integrated and serve as the basis for defining viable system growth options (e.g., gradual expansion of current systems, use of external facilities, development of a new computation system). A cost/benefit analysis is made of candidate options to determine the most promising one.

### 1.3.6 Generic Software Requirements

System software is defined to make the system user-oriented and to specifically accommodate transportation problems. The results of this function are used in the evaluation of system growth options and in future preliminary system design tasks.

### 1.3.7 Facility Survey

A brief survey (via literature search and telephone canvassing) of a cross section of simulation and analysis computer systems and techniques provides a reference of background material for the requirements definition phase and for the preliminary system definition phase.

### 1.3.8 Technology Forecast

A technology forecast study projects the state-of-the-art of applicable computer systems in the TASS time frame. The study includes cost trends and the impact of technology on specific techniques for the solution of transportation problems. The results of this task are used in the evaluation of potential system growth options and preliminary design decisions.

## 1.4 FY 72 RESULTS

All planned FY 72 activities were successfully completed. A brief summary of results follows.

### 1.4.1 TSC Resource/Utilization Study

1.4.1.1 System Capability - TSC's main on-site computer resources consist of seven small-to-medium sized computers organized into four essentially separate facilities. Three of the systems have display and terminal equipment. Five minicomputers (of which four are special purpose) are also available but do not provide any significant general support.

The TSC computers are quite adequate for many of the existing program computer applications. However, they are geared toward small scale programs that do not require interaction with large data bases, while the current trend is toward large system analysis and development projects with heavy CPU and large data base demands. In fact, some current TSC programs have grown with time and have been constrained by the limited power available.

During FY 72, processing time on at least ten off-site systems was utilized to supplement the computation support of the on-site systems. The computer systems ranged from medium-to-large scale and were utilized because of their size and/or available software.

1.4.1.2 Computational System Utilization - The magnitude of TSC's FY 72 computer usage (both on-site and off-site) was characterized in terms of equivalent CDC 6600 CPU hours. Actual problem application utilization was estimated at 845 hours. Adding 365 hours for system operations and maintenance and 650 hours for machine idle time resulted in a total of 1860 hours which is equivalent to the utilization of one CDC 6600 system. This does not imply that the present TSC resource utilization is equivalent in capability to the utilization of a CDC 6600 at TSC. It simply indicates the magnitude of present workload and capability for comparison to the projected workload for FY 77.

Computer system charges for on-site and off-site systems were estimated to total $1,377,000. This result is consistent with the estimated computer hours, since this charge is comparable to the annual lease charges for a CDC 6600 with appropriate peripherals. The computation expenses were approximately 8 percent of TSC in-house expenditures for FY 72. In comparison, firms involved in "hard" technology typically have computer expenditures of 4 percent while those involved in "soft" technology typically have computer expenditures of 20 percent.

An analysis was made of the pattern of utilization in the three types of processing: Business and Administration, Scientific, and Analog/Hybrid. The off-site workload (which was 14 percent of the total) was all "scientific" processing. Off-site systems have been used because projects required the use of programs written for other computer systems and because some programs were too large for the on-site systems.

### 1.4.2 FY 77 Program Projection

Analysis of TSC's programs from FY 71 through FY 73 shows that TSC is progressing satisfactorily toward meeting its growth strategy goals. TSC is developing a capability to manage large system programs in all areas of transportation and has made initial progress in developing computer tools in support of its programs.

TSC's budget growth is reasonably close to the goal contained within TSC's growth strategy. Recent data have indicated that a FY 77 TSC budget goal of $152 million may be unattainable. However, the trend is significantly upward, indicating that the goal may yet be reached at a later year. Of the $152 million, $44 million was projected to be direct in-house expenditures.

Program data parameters (program characteristics and in-house budget) were determined for the projected FY 77 programs. Each program was defined as some combination of functional characteristic such as planning, research, design, etc. The resultant data were adequate to provide a definition of TSC FY 77 program activity in a form that could be utilized in the computational demand projection process.

### 1.4.3 FY 77 Computational System Demands

The projection technique was designed to produce first-order approximations of the quantitative and qualitative demands of TSC in FY 77. It is felt that the results are valid indications of trends that can be used to evaluate the capability of TSC's computational systems to support future needs.

1.4.3.1 Qualitative Demand Parameters - These are parameters that relate to the computational environment and are typically difficult to express numerically. Each parameter was given a score which represented the significance of the parameter to the computer system users. The parameters were categorized as follows:

a. Software (18 parameters);

b. Man/Machine Interaction (18 parameters);

c. Data Management (10 parameters).

Results show that TSC needs will be oriented strongly toward user analysis aids. Examples of important features are problem-oriented languages, simulation languages, common data base, conversational interaction and interactive graphics.

1.4.3.2 Quantitative Demand Parameters - These are parameters that can be expressed numerically. Results were obtained for the following parameters:

a. CPU time (CDC 6600 base): 3800 to 10,500 hours;

b. Terminal usage: 45,000 to 126,000 hours or 23-63 man-years.

A preliminary analysis was also made of the required primary memory and secondary storage. Results are available in the MIT Final Report.

### 1.4.4 User Requirements Survey

Response to the survey was satisfactory; twelve of the thirtee surveys circulated to division chiefs were returned. Detailed results of the survey are presented in Appendix A.

Most of the division chiefs used their project managers to provide the information requested on the survey. The project managers, however, did not have the means to project their future computer system needs in the detail required for system design planning. Projected FY 73 computational expenditures show only a slight increase over FY 72, which is highly questionable. However, the qualitative portion of the survey provided valuable information on the characteristics of the projected computational system needs. The data reflect need for more and/or different support software and peripheral equipment. However, the potential of user analysis aids was not recognized, probably because TSC is in the early stages of growth in the utilization of computer tools.

Overall, the results of the survey were valuable in showing how program managers approach their computational system needs and in showing trends. It was a first step and should be iterated as the project managers gain experience in visualizing and estimating their needs. The questionable nature of the absolute results also supports the use of the independent computational demand projection process.

### 1.4.5 System Growth Options

A Request for Proposal (RFP) (Ref. 1) was generated as planned and the contract will be let in October 1972. Results from the completed FY 72 tasks will be inputs to the system growth options analysis.

### 1.4.6 Generic Software Requirements

MIT has initiated work in this area. Results of the computational demand projection will be the basis for definition of the generic software requirements.

### 1.4.7 Facility Survey

The results of the facility survey (Ref. 2) show that most large scale facilities have been designed to handle the unique needs of the centers they support. The system design trend is toward centralization of computer resources. System features which are widely utilized are time sharing, interactive terminals (including graphics) and problem-oriented languages. A good supply of pertinent data was provided which will be useful as reference material for future design studes.

### 1.4.8 Technology Forecast

The technology forecast (Ref. 3) will be input to the system growth options task and future design studies. The report covers advanced concepts and trends of processors, main memories, mass memories and system architecture.

## 1.5 CONCLUSIONS

The major conclusions reached in regard to computational requirements, based on the data available at the time of the study, are as follows:

a. The projected computational system demands of TSC in FY 77 will rise quite substantially over the present TSC capability. CPU usage for applications programs is expected to increase by four to ten times the FY 72 usage.

b. The increase in large computer programs requires access to powerful computer systems.

c. The need for user-oriented hardware and software tools will increase substantially over what is presently available.

Although TSC's growth may not be as rapid as was previously projected, the results of the FY 77 computer demand analysis are valid indications of the trend of TSC's needs. The next step is to update the requirements based on new data and to determine the means to meet TSC's growing needs.

# 2.0 TSC GROWTH STRATEGY

## 2.1 INTRODUCTION

The aim of TSC is to serve as the technical arm of DOT, involving itself in the application of modern technology and techniques to solve growing national transportation problems.

That TSC faces a challenge in an increasingly important and critical area is clear. That computers and computer techniques have been useful (perhaps essential) in transportation systems analysis to date is equally clear. For TSC to maintain a competent level of support to DOT, it is essential that it have adequate computational resources available to cope with both an increasing workload and an increasing complexity of transportation analysis. In determining the required growth of TSC's computational resources it was first necessary to describe the nature of TSC at a reasonable stage of its growth. FY 77 was selected as the target growth year, because of the lead time needed to implement a major system and also because TSC should complete a substantial part of its growth by FY 77. The analysis performed in projecting a picture of TSC in FY 77 consisted of identifying the goals of TSC and the projected scope of TSC program activity to meet these goals. Within this framework, pertinent program data parameters and program descriptions were developed for input to the computational projection process (as discussed in Section 4.0).

## 2.2 TSC GOALS

The Center was established (July 1, 1970) with the following objectives (Ref. 4):

a. To serve as a technical transportation resource for the Office of the Secretary (OST) and the operating administrations, with the capability and facilities necessary to assist in the solution of transportation problems;

b. To address significant intermodal transportation problems as defined by OST and the adminstrations;

c. To progressively improve the capability to manage large R&D programs as required by the administrations and OST.

Using these objectives and DOT policy direction (Ref. 5) as a guideline, a five-year TSC growth strategy (Ref. 6) was developed by TSC's Operating Directors. The short and long term elements of this strategy are:

a. Short Term (FY 71-73)

1. Demonstrate existing TSC capability in air transportation control systems. Expand capability to ground transportation control systems.
2. Accept and perform short range projects which will facilitate growth of in-house capabilities in areas of long range interest.

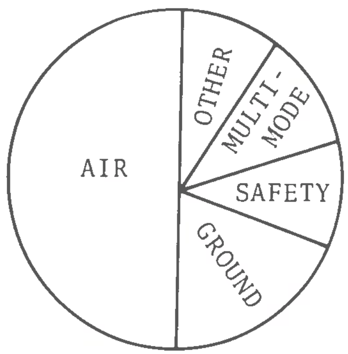
b. Long Term (FY 73-77)

1. Build and demonstrate capability to manage, design and develop total transportation systems.
2. Develop capability and supporting computer tools to perform transportation planning and analysis.

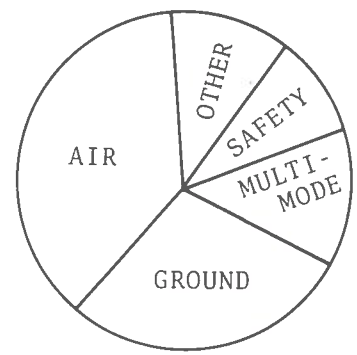
The funding chart in Figure 2-1 illustrates the trend toward achieving these goals. The FY 73 funding data represent information received by TSC from OST as of May 1972 and have been approved by the OMB but not by Congress. Comparison of the respective FY 71 and FY 73 funding and example programs shows that the short term goals are being achieved and that TSC is also increasing its attention to the long term goals. Total funding and average project funding have increased 96 percent and 120 percent, respectively, but the number of projects has increased by only 16 percent.

At its inception, TSC inherited personnel with special skills in the areas of electronic sensors, communication, and data processing for air transportation systems. Therefore, in FY 71, TSC became involved in many small, short-term projects which were concentrated in research and testing at the component level. Early TSC programs included: (1) prototype pilot warning indicator

FY 71




FY 73




| | FY 71 | FY 73 |
|---|---|---|
| FUNDING - $M | 24 | 47 |
| NO. PROJECTS | 63 | 73 |
| AVERAGE $/PROJECT-$K | 290 | 640 |
| NO. PROJECTS > $ 1M | 3 | 9 |
| Program Examples: | Design of Laser Fog Band Detector, Demonstration of Inertial/ILS Landing System, Operating Prototype of a Pilot Warning Indicator | Management of the Rail Tech. Program, Management of Dual Mode Program |

Figure 2-1 TSC Program Trend

(NASA, FAA); (2) demonstration of an inertial ILS landing system (NASA, FAA); (3) testing and evaluation of anti-hijacking equipment (FAA) and (4) prototype of a vehicle crash sensor (NHTSA). Since FY 71, TSC has broadened the scope of its technical expertise in the ground and multimodal transportation system areas, as well as in the air transportation area. For example, the FY 73 budget includes funding for such large, long-term programs as: (1) Advanced Air Traffic Management Program (OST); (2) Management of the Rail Technology Program (UMTA); (3) Dual Mode Program (UMTA); and (4) Management of the Airport Ground Traffic Control System Program (FAA). A complete list of the proposed FY 73 programs, including funding, is presented in Appendix B.

There is evidence that the goal of developing the necessary computer tools to perform planning and analysis is being achieved. Examples of software models, which have been or are being developed, include: (1) Dual Mode Cost Benefit Model (TST, FHWA, UMTA); (2) Airport Surface Traffic Simulator (FAA) and (3) Flow Control Model (FAA).

## 2.3 MAGNITUDE OF FUTURE TSC PROGRAM ACTIVITY

The magnitude of future TSC program activity was analyzed to develop a framework for a more detailed analysis of program budgets and program characteristics.

FY 77 budget data were obtained from TSC growth strategy data that included a projection of TSC's manpower and leverage factors. A leverage factor is the total TSC budget (in-house and contracted expenditures) divided by the number of technical personnel.

Projected technical and administrative manpower growth (Ref. 4) is presented in Figure 2-2. The continuous line represents the most likely manpower growth, while the dashed lines represent the upper and lower projection boundaries. By FY 77, the expected man-year level will be 1160. (Upper and lower boundaries are 1450 and 985, respectively.) Projected TSC technical manpower in terms of potential sponsors (OST, UMTA, etc.) is presented in Figure 2-3.

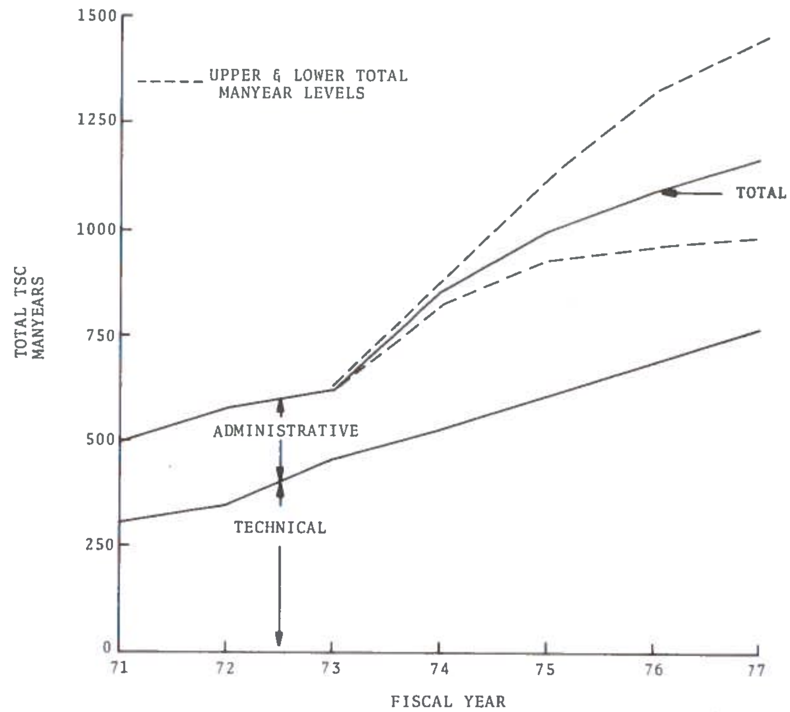



Figure 2-2 TSC Manpower Trend

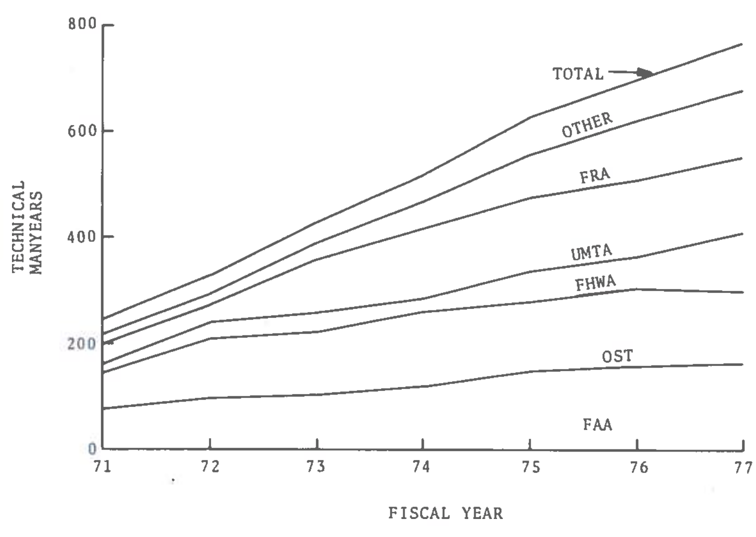



Figure 2-3 TSC Manpower Trend by Sponsor

These projections show that TSC manpower allocations for FY 77 are approximately equally divided between FAA, OST, UMTA and FRA, which is consistent with TSC's goals.

The estimated leverage factor for each sponsor for each year is presented in Table 2-1. The main factor in estimating leverage factors for each sponsor was the forecast of the type of work which TSC would perform for that sponsor. For FY 77, the following assumptions were made: (1) in-house research and development work - $50K-60K/manyear leverage; (2) preliminary planning and analysis - $100-150K/manyear leverage; and (3) heavy facility work - greater than $200K/manyear leverage. Examination of DOT and NASA technical organizations suggested that a leverage of approximately $200K/manyear is a reasonable objective for the type of system development work forecasted for TSC in FY 77. The trend toward a higher leverage factor is consistent with the goal of increased TSC management of large contracts.

TABLE 2-1 TSC LEVERAGE BY SPONSOR

| Customer \ Fiscal Year | 71 | 72 | 73 | 74 | 75 | 76 | 77 |
|---|---|---|---|---|---|---|---|
| FAA | 72 | 67 | 125 | 150 | 170 | 190 | 200 |
| OST | 87 | 92 | 140 | 150 | 150 | 150 | 150 |
| FHWA | 57 | 64 | 100 | 125 | 150 | 170 | 180 |
| UMTA | 75 | 182 | 200 | 240 | 240 | 220 | 220 |
| FRA | 47 | 71 | 110 | 150 | 240 | 250 | 250 |
| NHTSA | 64 | 59 | 100 | 140 | 170 | 190 | 200 |
| Coast Guard | 55 | 52 | 70 | 85 | 95 | 100 | 100 |

Figure 2-4 illustrates the TSC funding trend. One curve is a projection of TSC funding from FY 71 through FY 77, and the other curve is a rough estimate of the trend of TSC's percentage of DOT R&D funding from FY 71 through FY 77. TSC funding data were computed by multiplying each sponsor's technical manyears (Figure 2-3) by the customer's leverage factor (Table 2-1) and summing to give the total TSC funding. The dashed lines in Figure 2-4 represent upper and lower funding bounds and are a function of the manpower boundaries presented in Figure 2-2. The data shown for FY 71 and 72 reflect actual expenditures. FY 73 funding of $49.8M represents the amount approved by OMB. FY 74 through FY 77 data are projected and shown to grow to $152M by FY 77. Note that the TSC portion of the DOT R&D funding is projected to increase by 8 percent from FY 72 to FY 77. This increase in percentage is due to a projected expansion of TSC's role in performing R&D work for the various administrations within DOT.

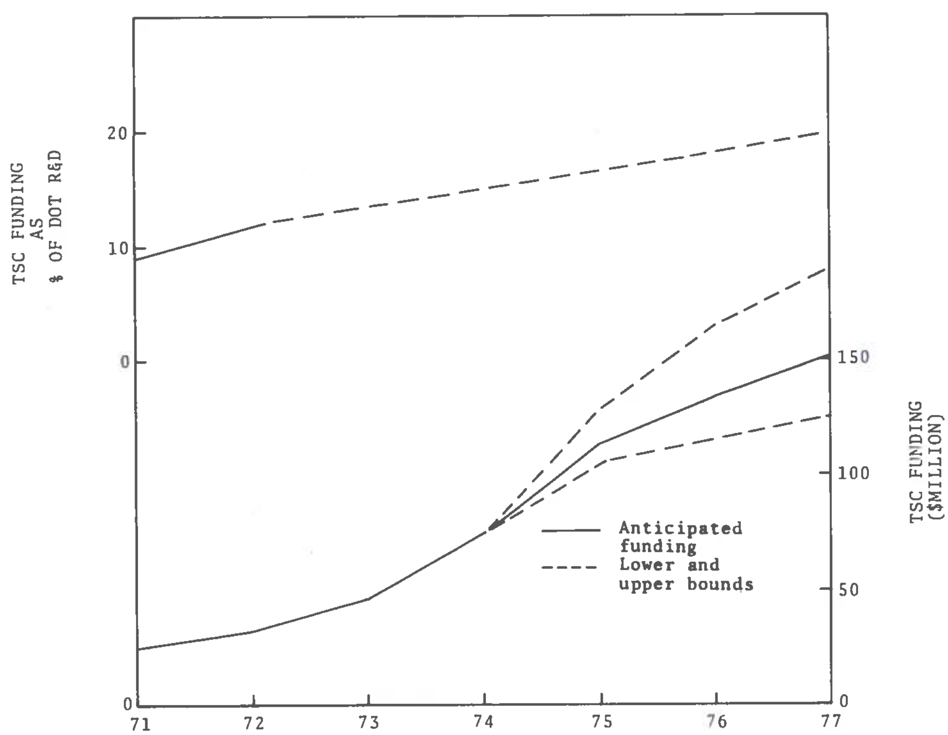



Figure 2-4 TSC Funding Trend

## 2.4 CONCLUSION

The analysis of TSC's growth strategy clearly indicated that TSC's growth is increasing at a rate justifying a detailed analysis of program impact on computational demand. A more detailed analysis was performed on projected FY 77 program activity in terms of program budgets and program characteristics and is presented in Section 4.0.

# 3.0 CURRENT COMPUTATIONAL SUPPORT

## 3.1 INTRODUCTION

A necessary task in planning for future computational demands is the evaluation of the present resources' ability to meet the demands. TSC currently employs a medley of on-site and off-site computer systems to obtain the computational support for its administrative and project workload. To put the projected FY 77 computational demands in the perspective of the present resources, it is important to determine the capabilities of these systems and the nature and the extent of their use. This section first identifies the computer systems used by TSC personnel during FY 72 and summarizes their capabilities; second, the pattern of use of these systems (who, how much) is delineated and the factors influencing this use examined.

## 3.2 COMPUTATION SYSTEM CAPABILITIES

TSC's computer utilization is administered by the Data Services Division and summarized monthly by that division in the User Accountability Report. Examination of the monthly reports for FY 72 indicates that during the fiscal year TSC personnel made direct expenditures for the use of eighteen different digital computer systems - eight on-site systems and ten systems owned and maintained outside TSC (listed in Table 3-1). In addition, TSC personnel used at least two other systems in conjunction with R&D contracts, for which TSC incurs no charges and maintains no utilization records (systems no. 19 and 20).

### 3.2.1 <u>On-Site Systems</u>

Seven of TSC's on-site computer systems are organized into four autonomous facilities: (a) the Honeywell facility; (b) the hybrid facility; (c) the multimode simulation facility; and (d) the central facility. The eighth on-site system used for general purpos digital support is a smaller computer system used on a pure standalone basis. These on-site facilities are described in detail - in

TABLF 3-1 COMPUTER SYSTEMS USED BY TSC PERSONNEL - FY 72

TSC On-Site Computer Systems

| | |
|---|---|
| Honeywell Facility | 1. Honeywell H-832 |
| | 2. Honeywell DDP-516 (GOTS) |
| | 3. Honeywell DDP-516 (TAG) |
| Hybrid Facility | 4. XDS 9300 (Beckman 2200 analog) |
| Multimode Simulation Facility | 5. Digital PDP-10 |
| | 6. Honeywell DDP-516 |
| Central Facility | 7. IBM 7094-II (IBM 360/30 - I/Ø) |
| Independent | 8. Honeywell DDP-516 (TIF) |

Off-Site Computer Systems

| Organization | |
|---|---|
| 9. Smithsonian Astrophysical Observatory | CDC 6400 |
| 10. Control Data Corporation (Cybernet Service) | CDC 6600 |
| 11. Massachusetts Institute of Technology | IBM 360/75 |
| 12. MITRE Corporation | IBM 370/155 |
| 13. Interactive Data Corporation | IBM 360/67 |
| 14. Tymshare, Inc. | XDS 940 |
| 15. First Data Corporation | DEC PDP-10 |
| 16. GSA Timeshare Service | GE 440 |
| 17. The Computer Company | IBM 370/155 |
| 18. Control Data Corporation | CDC 6400 |
| 19. Harvard University | IBM 360/65[1] |
| 20. Systematic Data Processing Services | IBM 370/155 |

[1] No longer available.

terms of physical configuration, available software, and typical applications - in a report generated for this project (Ref. 7); a summary is presented below, and salient features of each computer system are included in Appendix C.

3.2.1.1 The Honeywell Facility - The Honeywell facility consists of three operationally independent computers: the Transportation Animated Graphics (TAG) DDP-516, the Graphics Oriented Transportation Simulation (GOTS) DDP-516, and the H-832. The system contains two high speed couplers - one to connect each DDP-516 to an H-832 channel. The Honeywell facility is open-shop in the sense that there is no operator (i.e., each user operates the computer(s) himself).

Although the H-832 has hardware segmentation and other sophisticated hardware features to facilitate multiprocessing, multiprogramming, or timesharing, Honeywell made very few H-832's (and H-632's, the single CPU version of the machine), so that the software one normally expects for this size machine never materialized. As a result, there is no software for multiprocessing or timesharing. Programs exist to permit transmission (and conversion) of files between the H-832 and the DDP-516's and to provide run-time communication between programs in different computers, but the H-832 is rarely used in conjunction with either the TAG or the GOTS systems.

3.2.1.2 The Hybrid Facility - The hybrid facility consists of an XDS 9300 digital computer and a Beckman 2200 analog computer. The facility also contains an EAI-580 analog computer that is not connected to the hybrid computer. A general aviation trainer (GAT) can be used under control of the hybrid computer or with the EAI-580 and the PDP-10. The hybrid facility is used in open-shop mode.

The XDS 9300 digital computer is a second generation computer run as a tape and card oriented batch system. It is used in both hybrid and in stand-alone mode. Typical applications include real-time, man-in-the-loop simulations involving the GAT and fast-time 4-D guidance simulations. The latter is chiefly a digital application.

3.2.1.3 Multimode Simulation Facility - The multimode simulation facility consists of a PDP-10 and a Honeywell DDP-516 with a Sanders 900 display system. A high-speed interface connects the PDP-10 and the DDP-516. The PDP-10 is also connected to the EAI 580 (and thus to the GAT) of the hybrid facility with an experimental link which is not currently operational.

The PDP-10 is a time-shared computing system without paging but with core swapping which, with the machine's 80K 36 bit words, gives an apparent core of 256K words.[1] It also has the capability of doing real-time work and background multiprogramming work. The DDP-516 is an open-shop system that supports one user at a time. The 516 in this facility is chiefly a graphics support system.

This facility is used chiefly for real-time simulations that involve human interaction. Typical applications are an airport surface traffic model (AGATS project) and a simulation of the Atlanta air space that involves a human air traffic controller (AATMS project). The PDP-10 has become a popular machine for scientific work, and thus the basic systems software, as well as much application software, is available through the computer manufacturer.

3.2.1.4 Central Facility - The central computing facility consists of an IBM 7094, an IBM 360/30, and an assortment of punch card accounting machines. The central facility is operated in closed-shop, batch-oriented mode. The 7094 is a second generation, tape-oriented system that receives I/O support from the 360/30; its operating system is quite primitive by today's standards. The 360/30, besides doing all pre and post processing for the 7094, is used for utility processing, paper tape work, CALCOMP microfilm and pen plotting.

This facility is used chiefly for business and administrative processing.

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[1] PDP-10 systems can be upgraded to include paging hardware, dual CPU's, and considerably more core than the 80K words in the multimode simulation facility.

3.2.1.5 Stand-Alone Minicomputers - In addition to the four facilities discussed, a number of minicomputers are in use at TSC (listed in Table 3-2). Only the TIF DDP-516 (by far the largest of the five mini systems) is used as a general purpose computer. The other four computers are used for specialized applications. The two PDP-11's are used primarily to reduce and to process analog field data and can be used in mobile units. The PTH DDP-516 was recently obtained and in its current minimal configuration cannot be used for general purpose computing. The IBM 4π is a special purpose aerospace digital computer owned by NASA and not applicable to general purpose utilization.

TABLE 3-2 STAND-ALONE MINICOMPUTERS

| Computer | Organization |
|---|---|
| Honeywell DDP-516 | TIF |
| DEC PDP-11 | TIF |
| DEC PDP-11 | TEC |
| Honeywell DDP-516 | PTH |
| IBM 4π | PGS |

### 3.2.2 Evaluation of On-Site Systems (Ref. 7)

The TSC facilities are well suited to many specialized applications (image processing, graphics, etc.), and TSC personnel have developed excellent software tools to get the most out of the available equipment. The small systems in use at TSC tend to be more flexible, as small user populations and small operating systems allow one to modify a system to make it more responsive to the individual user.[1] It should be noted, though, that the TSC capability is geared towards small scale programs that normally do not require

[1] It is interesting to note that most such changes are made to handle interactive graphic input/output. If a large control computer with satellite graphic processors were used, this flexibility would not be lost, since changes would not normally involve the operating system of the larger processor.

interaction with large data bases. Programs that have grown with time (such as the FA-206 Flow Control Simulation on the GOTS system) have been severely constrained by the limited power of individual facilities. If the planned reduction in the number of projects with relatively small computing requirements and increase in the number of large systems analysis and development projects with heavy CPU and large data base demands continues, the on-site facilities will soon be inadequate.

A number of shortcomings of the TSC facilities are delineated below. Many of these could be overcome by curtailing the current proliferation of systems. Ideally, there would be one central facility, with a number of satellite processors to perform the specialized input-output functions. The DDP-516 in the Multimode Simulation Facility is a typical example of such a satellite. When simulations are run on the Multimode Simulation Facility, the bulk of the computations are performed on the PDP-10, while the graphic input and output are handled by the DDP-516. Such a consolidation of facilities would provide more processing power and more primary memory for individual programs as well as a larger unified file system. It is likely that such a facility would lead to increased use of in-house computers because of the resulting commonality of software and increased processing power and data base capability.

3.2.2.1 Continuity of Service - With the possible exception of the central facility, less emphasis is placed on continuity of service at the separate TSC facilities than one normally finds at a large unified installation. The reasons for this are not clear, although the specialized nature of most applications and the absence of duplicate equipment in the smaller systems are certainly contributory. For example, when a hardware (e.g., paper tape reader or disk drive) failure occurs on the TAG-516, all computer work on projects using that system comes to a standstill. If the TAG computer were a true satellite graphics processor for a large system, some program development could continue and, depending on the nature of the hardware failure, the TAG computer could be partially usable.[1]

3.2.2.2 Duplication of Effort - The existence of many computers requires maintenance of an operating system for each. There have been attempts at standardization, such as using the GOTS disk operating system (DOS) on all DDP-516's, but differences in user requirements and preferences have led to separate maintenance of these systems. An even greater duplication of effort can be found in the development of utility software for the various systems. Different editors, graphics packages, etc., are maintained on each computer. Much of this duplication of effort could be avoided in a facility with a large central computer and satellite mini-processors operated under enforced standards.

3.2.2.3 Program and Data Conversion - As computers begin to be used for more complex system level efforts, problem solutions will require use of many interrelated computer programs and access to a number of data bases. One-of-a-kind peripheral devices (e.g., the Calcomp plotter on the GOTS system, the Air Traffic Control CRT in the Multimode facility, or the GAT trainer in the hybrid facility) may be required in one or more steps of a solution. The current TSC computing environment will require programs, data, or both to be transferred from one computer to another. Such transfers require considerable effort because of incompatibility of operating system interfaces, of computer languages, of file layouts, and of data representation. For example, to make possible further expansion of the Flow Control Simulation (currently running entirely on the GOTS DDP-516), the feasibility of using both the H-832 (for processing) and the DDP-516 (for graphics) was studied. It was found that many program modifications would be required to

[1]The H-832 was meant to play the role of a central computer in the Honeywell facility, but its hardware and software status prohibit the use of, for example, its file system as a backup to the DDP-516 file systems.

adapt the program for operation on the H-832. Data base conversion from the 516 to the H-832 would be equally tedious.

3.2.2.4 Lack of Computing Power - The computing power of a facility can be roughly characterized by the power of its instruction set, its CPU speed, its primary memory size and speed, its ability to handle I/O requests, and the size and speed of its secondary memory (i.e., disk and drum system). These factors affect two things that will be of greater concern to TSC as the character of its workload changes: the processing capability and the file system capability. Although the combined power of all TSC facilities is considerable, no one computer is capable of handling a job with a heavy processing or large data base demand. The IBM 7094 has no disk and thus can only deal effectively with sequential tape-resident data. Its cycle time is relatively slow, and its core memory is small. The PDP-10, in its current configuration, cannot be considered more than a small-to-medium scale computer system. The other two facilities have even lower individual capabllities.

### 3.2.3 Off-Site Systems

In addition to the on-site computer systems, TSC personnel have access to a number of non-TSC, timesharing, remote batch, and batch oriented systems. During FY 72, processing time on at least ten of those systems was used to supplement the computation support available from on-site systems. The capabilities of these systems--physical configuration, available software, and mode of access--are summarized in tabular form in Appendix C. These systems fall into two categories: medium-to-large scale third generation batch oriented systems (9 - 12 of Table 3-1) and time-sharing systems (13 - 18 of Table 3-1). Between them, they offer a tremendous range of processing power, mode of access, and software capabilities. Unfortunately, these are not always available in the desired combinations.

## 3.3 COMPUTATION SYSTEM UTILIZATION

### 3.3.1 Magnitude of Computer Utilization

Characterizing the computer utilization of an organization which uses twenty diverse systems was a difficult task. Two approaches were taken to determine the magnitude of computer utilization during FY 72. One was to determine the computational charges and the other was to use the common approach or translating the computation hours for various machines into equivalent hours on a single machine. The latter approach can only suggest the magnitude of computation performed at TSC, because the technique rests on the determination of transformation ratios to be applied to each machine vis-a-vis a "common denominator" processor. These ratios should be based on benchmark programs which typify the work performed on each of the individual machines. But there may be no "typical" workload. Except in cases involving a static mix of standardized tasks, it is difficult to devise a set of benchmarks that accurately represent the spectrum of work performed on any large or medium scale computer system. At TSC, the limitations inherent in such approaches are magnified 20 times. Despite these problems, it was necessary to describe the scope of current computer usage at TSC in terms that could be used in assessing the import of the projected FY 77 demands.

3.3.1.1 Computation Hours - Estimation of total computation hours used by TSC personnel during FY 72 in terms of a single, common machine required the following for each machine employed: (1) the number of computation hours used and (2) the transformation ratio used to compute the equivalent hours. The difficulties associated with machine comparisons, noted above, prescribe that the transformation ratios developed be interpreted as approximations. The ratios used (see Table 3-3) are based on the accumulated results of several years of benchmark and application experience of TSC personnel. The computation hours utilized on each machine, on-site and off-site, are taken from TSC's User Accountability Reports, with the exception of the data for the Honeywell equipment which is from the daily log. This information and the equivalent common machine (CDC 6600) computation hours are shown in Table 3-3. In all cases, the reported full year figures are extrapolations based on less than the full year's data. As reporting and cost allocation policies have differed from facility to facility, it was necessary to make an overall assumption for the percentage breakdown between problem application time and systems maintenance time. It was assumed that a minimum of 70 percent of total computation hours could be considered to be utilization; thus, at most, 30 percent of any computer's computation time has been designated systems and maintenance computation time and not categorized as utilization.

TABLE 3-3 FY 72 COMPUTATION HOURS

| | Estimated Fiscal Year CPU Hours | Conversion Ratio | Equivalent CDC 6600 CPU Hours | |
|---|---|---|---|---|
| IBM 7094II | 960 | .15 | 144 | |
| Honeywell 832 | 675 | .25 | 169 | |
| Honeywell 516 (GOTS) | 459 | .10 | 46 | |
| Honeywell 516 (TAG) | 231 | .10 | 23 | |
| Honeywell 516 (TIF) | 184 | .10 | 18 | |
| Honeywell 516 (PDP-10) | 400 | .10 | 40 | |
| DEC PDP-10 | 300 | .17 | 51 | |
| XDS 9300 | 1167 | .20 | 233 | |
| | On-Site Sub Total | | | 724 |
| SAO: CDC 6400 | 35 | .43 | 15 | |
| CDC: CDC 6600 | 63 | 1.00 | 63 | |
| MIT: IBM 360/75 | 70 | .45 | 32 | |
| Harvard: IBM 370/155 | 3 | .40 | 1 | |
| MITRE: IBM 360/50 | 13 | .11 | 1 | |
| IDC: IBM 360/67 | -- | .33 | -- | |
| T/S: XDS 940 | 38 | .01 | -- | |
| FDC: DEC PDP-10 | 49 | .17 | 8 | |
| GSA: GE 440 | 12 | .07 | 1 | |
| | Off-Site Sub Total | | | 121 |
| | Center Total | | | 845 |

As Table 3-3 shows, TSC personnel performed computations equivalent to 845 CDC 6600 CPU hours. This figure represents approximate chargeable hours of application utilization only and does not include system idle time or systems and maintenance operations time. Assuming that systems and maintenance amounts to 30 percent of total utilization, the equivalent total utilization for FY 72 is 1210 CDC 6600 CPU hours. Further, assuming an average system idle time[1] of 35 percent, the required system (CDC 6600) availability would have been 1860 hours. In sum, TSC's FY 72 computer usage can be exemplified by a single CDC 6600 with the following utilization:

| | | |
|---|---|---|
| Actual Utilization | 845 hours | (45%) |
| Systems Operations and Maintenance | 365 hours | (20%) |
| Machine Idle Time | 650 hours | (35%) |
| Total Available Hours | 1860 hours | (100%) |

3.3.1.2 Computation Charges - Computation charges, as well as computation hours, are a good indication of the magnitude of computer utilization.

The computation charges for FY 72 are also extrapolations of data taken from TSC's User Accountability Reports, except for those for the Honeywell equipment which are based on the extrapolated computation hours and anticipated FY 73 hourly charges for that equipment.[2] As Table 3-4 shows, in FY 72 TSC charged approximately $600K for on-site computer support and another $200K for the purchase of computer time from off-site facilities. These two figures, however, are incommensurable: the charges for the use of off-site facilities includes the costs to the vendor of both leasing (or buying) and operating the computer system. The listed charges for the use of TSC's on-site facilities, however, comprise operating

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[1] System idle time is time that cannot be "captured" and is typically 20-50 percent of the total available time.

[2] Projected FY 73 charges are based on FY 72 costs and usage.

TABLE 3-4. FY 72 COMPUTATION EXPENSES

| Equipment | Estimated Full Year Charges $K | | |
|---|---|---|---|
| IBM 7094II | 127.1 | | |
| Honeywell 832 | 63.5 | | |
| " 516 (GOTS) | 27.2 | | |
| " 516 (TAG) | 5.6 | | |
| " 516 (TIF) | 8.4 | | |
| " 516 (PDP-10) | 18.8 | | |
| DEC PDP-10 | 220.4 | | |
| XDS 9300 | 131.3 | | |
| | | On-Site Sub Total Charged | $ 602.3K |
| | | On-Site Depreciation | $ 572.0K |
| SAO:CDC 6400 | 21.9 | | |
| CDC:CDC 6600 | 89.4 | | |
| MIT:IBM 360/75 | 29.8 | | |
| Harvard:IBM 370/155 | 1.7 | | |
| MITRE:IBM 360/50 | 5.5 | | |
| IDC:IBM 360/67 | 5.7 | | |
| T/S:XDS 940 | | | |
| FDC:DEC PDP-10 | 49.3 | | |
| GSA:GE 440 | | | |
| | | Off-Site Sub Total for Time Purchase | $ 203.3K |
| | | Center Total | $1377.6K |

expenses only, since TSC owns all of the eight systems - except the I/O processor (IBM 360/30) for the IBM 7094. The real "cost" of using these systems should include depreciation charges. The purchase prices of the eight on-site systems total $2,860K; assuming five-year, straight line depreciation, the annual depreciation charge would be $572K. Therefore, TSC's FY 72 computation utilization could be characterized by total computation charges of $1377K, comprising $602K for on-site operating and rental costs, $572K for depreciation of on-site equipment, and $203K for the purchase of computer time from off-site facilities.

3.3.1.3 <u>Conclusions</u> - The results of the two examinations are consistent. The 1860 CDC 6600 CPU hours represent a single shift for that machine, and the computation charges of $1377K are equivalent to the annual rental cost of a CDC 6600 with peripherals resembling those in use at TSC-which would lease for approximately $100K per month or $1.2 million annually. Thus, the magnitude of computer work performed by TSC personnel during FY 72 is equivalent to that which could be provided by a single CDC 6600. These figures in no way imply that such a machine should or could have supplanted those which actually provided the computational support; they are merely indicative of the scope of computer work performed and are to be used to place the projected FY 77 computation demands in perspective.

Although the computer hour and budget data represent the absolute magnitude of computer support provided during FY 72, they give no indication of the relation of TSC's computation expenses to its total in-house budget. Data as of May 31, 1972 indicate that TSC FY 72 in-house expenditures (which exclude contract expenditures) should be approximately $18 million, including computer depreciation charges. Thus, computation expenses equal approximately 8 percent of the in-house budget for FY 72.

Comparison of this figure with industry averages indicates that TSC was still oriented toward hardware testing and component design - generally termed "hard" technology - in FY 72. Computer expenses for firms involved in "hard" technology are typically near 4 percent of their project budgets, while those for firms in the "softer" sciences - econometrics, preliminary systems evaluation, modelling - are near 20 percent of project budgets.[1] TSC's average (computer expenditure/in-house project budget) ratio is above that of hardware oriented industries, but its evolution to date has left it considerably under that of firms involved in the "soft" sciences.

### 3.3.2 Pattern of Utilization

In addition to the general magnitude of computer usage at TSC, the pattern of this usage was analyzed. The details of the FY 72 computer utilization analysis are discussed in Reference 8, which was generated for this task. A summarization follows.

TSC's User Accountability System distinguishes three types of processing: Business and Administrative, Scientific, and Analog/Hybrid.[2] It should be noted that the accountability system did not provide a complete picture because it did not include utilization data for the Honeywell facility, which performed 35 percent of the directly funded computer usage. Nevertheless, the User Accountability Reports were analyzed to determine any significant patterns or trends of utilization.

In FY 72, TSC personnel made use of twenty different computer systems: eight on-site systems and twelve off-site systems. This indicates that a significant (although difficult to determine) portion of the computer support required was, for various reasons, obtained outside the Center. Of the total 845 equivalent CDC 6600

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[1] Sussman, Joseph, "Computer Use in Engineering Consulting Operations," Internal Memorandum to TASF Program Office from MIT Transportation Computer Use Group, July 1972.

[2] This usage breakdown is that used in the User Accountability system for accounting convenience. Analog/hybrid processing is, of course, a type of scientific use; unless stated, "scientific" is used here to mean all scientific processing except analog/hybrid use.

CPU hours estimated to have been used, 120, or about 14 percent were run on off-site equipment. The dollar cost was slightly over $200,000 - a 20 percent increase over the previous year - but this cannot be compared to the dollar charges imposed for the use of on-site equipment which, as was described in Section 3.3.1.2, do not generally contain any charge for defraying the lease or purchase price of the machine used. FY 72 data were examined to determine the pattern of off-site utilization.

The User Accountability Report for March 1972, which covers three quarters of the fiscal year, shows that most of the Business and Administrative processing was performed on-site on the central facility (IBM 7094-360/30), constituting 74 percent of that facility's workload. Also, 100 percent of the Analog/Hybrid processing was performed on the on-site hybrid facility (XDS 9300, Beckman 2200), accounting for almost all of that facility's workload.

The scientific utilization depicted by the User Accountability Reports was quite different. The utilization breakdown was 31 percent on-site and 69 percent off-site, which was comparable to the FY 71 percentage split. These results indicate that it is the scientific processing requirements which have necessitated the use of the twelve off-site computer systems; in congruence with this, the User Accountability Reports show that virtually 100 percent of the processing performed on off-site systems was scientific utilization.

There are at least two reasons for the heavy reliance on off-site systems by TSC's scientific users. First, many of the current projects require the use of programs written for third generation computers incompatible with any within TSC. To avoid the time and expense of conversion, the users have sought the appropriate system off-site. Second, the eight small-to-medium TSC systems arranged in four autonomous facilities are oriented toward programs that are relatively small in scale and do not require access to large data bases (see Section 3.1.2). Several FY 72 transportation programs have required computer support of a scale that simply could not be provided by TSC's current on-site equipment. Two examples of this are the Dual Mode and Air Traffic Control Radar Beacon System (ATCRBS) Programs, both of which are heavy users of the CDC 6600. The cost/benefit model developed for the Dual Mode Program required 97,000 sixty-bit words of core storage on the CDC 6600, far exceeding the capacity of any TSC on-site computer. The Radar Beacon Simulation for the ATCRBS Program utilized computer runs requiring up to six hours of CDC 6600 CPU time which, for this particular simulation, would require six continuous days of PDP-10 CPU time. Again, this level of support simply could not be provided with the on-site equipment TSC now possesses.

As the current trend continues away from projects with relatively small computing requirements and toward those in the "softer" sciences with heavy CPU and large data base demands, this problem will become increasingly acute.

# 4.0 FY 77 COMPUTATIONAL DEMANDS

## 4.1 INTRODUCTION

A study was undertaken in conjunction with the MIT School of Civil Engineering to consider the magnitude and nature of the computer needs of TSC in FY77. This study comprised four separate steps: (1) Projection of pertinent FY 77 program data parameters; (2) a study of the computer use and computer techniques in contemporary transportation programs; (3) a study of the computer needs of various classes of computer users involved in a transportation program; and (4) first-order projection of TSC's FY 77 computation system demands based on the results of steps 1, 2 and 3.

The projection process was initiated early in FY 72 and reflects FY 77 program projection data available to TSC in November 1971. Data now available to TSC indicate that, due to future manpower limitations and an expected decrease in planned total DOT R&D funding, the scope of TSC's FY 77 programs may be less than those presented in this report. However, because the projection methodology produces first-order approximation data parameters, the results are valid as indications of the required trend of TSC's computational system demands. Further refinements will be made during future project requirement studies.

Step 1, the projection of FY 77 program data parameters, is discussed in Section 4.2; Steps 2, 3, and 4, which constitute the Computational Demand Projection Process, are discussed in Section 4.3.

## 4.2 FY 77 PROGRAM DATA PARAMETERS

FY 77 program parameters - the TSC in-house budget and characteristics of each program - were required for input to the computational demand projection process described in Section 4.3. The analysis of TSC goals and growth strategy described in Section 2 provided the boundary constraints used in developing the program parameters.

A list of candidate FY 77 programs is presented in Table 4-1. Programs were categorized as: (1) existing programs - those programs which the Center is presently working on and which will extend to FY 77 and (2) new programs - those programs which the Center is not now working on but may be involved with in FY 77. The "existing" programs are those listed in the TSC FY 73 OMB supplemental document (Ref. 9) and the "new" programs are based on the forecasts provided in the "New Technology Opportunities Program" (Ref. 10). A brief description of the projected FY 77 programs is provided in Appendix D. The funding estimates for the twenty programs, shown in Table 4-1, were constrained by the following guidelines: (1) a TSC budget in FY 77 of $152M; (2) existing and new program budget approximations contained in References 2 and 3; and (3) a program area mix (safety, air, ground, etc.) consistent with the long range goals of TSC.

The asterisks in Table 4-1 identify seven programs whose combined funding is approximately 70 percent of the total FY 77 budget. These seven programs, in combination, provide a picture of the major type of project activity which TSC's computational system resources must support.

Each program was analyzed to determine the functional characteristics of the in-house activity required for the program. The program analysis was based on direct TSC involvement and expenditures, because the computational system requirements to be determined are those resulting from direct needs by TSC personnel (and not the needs of out-house contracts). Of the various methods to describe program characteristics, that used in the TASF Planning and Approach document (Ref. 11) was selected. Programs were described as comprising one or more of the following functional tasks: (1) Program control; (2) planning; (3) research; (4) analysis; (5) design; (6) evaluation; (7) fabrication; and (8) demonstration. These program characteristics are defined in Appendix E.

For each FY 77 program, an estimate was made of the direct in-house budget and the percentage to be devoted to each of the functional tasks. Results are shown in Table 4-2. The total in-house

TABLE 4-1 TSC FY 77 PROGRAM MIX

| Program Area | Program Name: Existing Program | Program Name: New Program | Probable Sponsor | Total Funding $M |
|---|---|---|---|---|
| Marine | Navigation (Aid to) | | USCG | 1 |
| | | Vessel Traffic System | USCG | 1 |
| Pollution | | Surface Pollution | OST | 2 |
| Noise | | Airport Noise | FAA | 5 |
| Safety | | Intersection* Improvement | FRA/ FHWA | 13 |
| | | Emergency Medi- cal Service | OST | 2 |
| Air | Adv. Air Traffic Man. Sys.* | | FAA | 14 |
| | Future Data Processing | | FAA | 1 |
| | Ground Guidance & Control | | FAA | 2 |
| | Microwave Landing Sys. | | FAA | 2 |
| | Satellite System | | FAA | 5 |
| | | V/STOL* | FAA | 14 |
| Ground | Rail Sys. Support Tech. | | UMTA | 4 |
| | | Fed. Freight RR* | FRA | 7 |
| | | Near Term Improv. in Mass Transit* | UMTA | 7 |
| | | Tract Levitated Vehicle | FRA | 3 |
| | | Balance | OST | 3 |
| | | Red. Tunnel Cost | OST | 2 |
| | | Urban Congestion* | UMTA/FRA | 19 |
| Multi-Modal | Dual Mode* | | UMTA | 45 |
| | | | | 152 |

*The sum of these projects comprise 70 percent of the budget.

## TABLE 4-2 PROGRAM FUNCTION CHARACTERISTICS

| Program | Est. In-House Fund. ($M) | Program Functions | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Planning % | Research % | Sys. Anal. % | Design % | Evaluation % | Demonstration % | Program Control % |
| Dual Mode | 7.6 | 10 | 5 | 30 | 20 | 15 | 10 | 10 |
| Urban Congestion | 6.7 | 5 | | 30 | 20 | 15 | 20 | 10 |
| Balance | 2.7 | 80 | 15 | | | | | 5 |
| Rail Efficiency | 2.2 | 25 | | 50 | 15 | | | 10 |
| Near Term Improvement | 2.2 | 10 | 10 | 25 | 10 | 25 | 10 | 10 |
| TLV | 1.1 | | 15 | 20 | 30 | 15 | 10 | 10 |
| Rail Sys. Support Tech. | 1.3 | | 10 | | 20 | 40 | 20 | 10 |
| Tunneling | 0.7 | | 30 | 20 | 20 | 10 | 10 | 10 |
| V/STOL | 4.7 | 30 | 30 | | 5 | 20 | | 15 |
| AATMS | 4.7 | 10 | | 40 | 20 | 15 | | 15 |
| Future Data Proc. | 0.7 | | 20 | 10 | 25 | 25 | 10 | 10 |
| Microwave Landing Sys. | 0.8 | | | 20 | 25 | 25 | 15 | 15 |
| Ground Guidance System | 0.8 | | | 20 | 30 | 20 | 20 | 10 |
| Satellite | 1.6 | | 15 | 20 | 40 | 15 | | 10 |
| Vessel System | 0.3 | | | 20 | 50 | 10 | 10 | 10 |
| Navigation | 1.1 | 10 | 10 | 30 | 30 | 5 | 5 | 10 |
| Intersection Improvement | 2.2 | | 5 | 20 | 45 | 20 | | 10 |
| Emergency Med. Service | 0.7 | 80 | | 20 | | | | |
| Surface Propulsion | 0.8 | | 50 | | 30 | 15 | | 5 |
| Noise Reduction | 1.5 | | 30 | 50 | 10 | | | 10 |

budget of $44 million is consistent with the projected manpower level. The data from Table 4-2, along with the program descriptions, were input to the computational demand projection process.

## 4.3 COMPUTATIONAL DEMAND PROJECTION PROCESS[1]

### 4.3.1 Introduction

The Computational Demand Model developed by the MIT Transportation Computer Use Group comprises the last three of the four steps[2] employed to determine the magnitude and nature of the computer needs of TSC in FY 77. The specific tasks performed were:

a. Review of Historical Transportation Projects - A study of the use of computers and computer techniques in contemporary transportation programs to gain insight into the nature of modern day usage in the field.

b. Computer Use Characteristics Study - A study of the computer needs of various classes of computer users involved in transportation programs and the importance of various computer system features to these users. This study viewed the computer from the user/programmer viewpoint as opposed to the system designer's viewpoint.

c. A projection of the in-house computer demands expected to be generated by the TSC FY 77 program mix described in Section 4.2.

The first two of these tasks were relatively independent studies designed as inputs to the third task; they are described in Sections 4.3.2 and 4.3.3, respectively. The approach to and results of the more specific third task, the projection of TSC's FY 77 Computation Demands, are delineated in Section 4.3.4.

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[1]This section is based on Reference 12.

[2]The first is the projection of TSC's FY 77 Program Mix.

### 4.3.2 Review of Historical Transportation Projects

The first task was addressed by studying the computer use methods of seven varied transportation projects. Case studies 1 and 7 covered university research and design projects, and case studies 2 through 6 covered projects of a medium-sized transportation consultant firm. The project studies were:

a. Case Study 1: Bus Allocation

The computer usage of a university research project was explored. The general purpose of the project was to develop computerized techniques for the allocation of buses, in real time, to varying passenger demands. Extensive use was made of timesharing computer systems for system simulation. The total project cost was $1.5 million, with computer costs of $180,000.

b. Case Study 2: Model Validation Project

The general purpose of the project was to use existing software to model the Boston transportation system as a network. During the project, over 300 magnetic tapes were maintained for project data. The total project cost was $350,000, and computer costs were $70,000.

c. Case Study 3: Intercity Transportation Effectiveness Model Development

This project was almost exclusively a model development effort. An extensive battery of programs for the analysis of air travel was designed and implemented. A large machine - 100,000 sixty-bit words - was used to capacity. The total project cost was $300,000 and computer costs were $150,000.

d. Case Study 4: Intercity Transportation Effectiveness Model Analysis

This project involved the use of the Case Study 3 model to obtain predictions of future results of Civil Aeronautics Board policy decisions. Much effort was spent in data acquisition. The total project cost was $400,000 and computer costs were $200,000.

e. Case Study 5: Intracity Travel Analysis

This project included a mix of software development, use of existing software, and data acquisition and analysis. Intracity travel data by time of day was obtained and analyzed. The project cost was $60,000, and computer costs were $10,000.

f. Case Study 6: Northeast Corridor Transportation Planning Project, National Bureau of Standards

This project was a major effort carried out by the Department of Transportation to study intercity transportation in the Boston to Washington corridor. The portion included in the case study is the in-house work done at NBS, which served as a contractor to DOT. The case study, therefore, represents a governmental transportation project which used computers. The total project cost at NBS was $3.0 million with 10 percent being spent for computer time.

g. Case Study 7: MIT Guideway Design

This project is an on-going effort in the MIT Department of Mechanical Engineering. The phases included in the case study involved the use of hybrid (analog-digital) computers for the analysis of physical systems, as well as the use of purely digital computers. The total project cost is $70,000 per year, with $7,000 being spent for computer time.

In order that the results of the analysis of the above seven projects be as useful as possible, they were combined into an organized data base. This data base comprises project evaluation templates (a standard form which was completed for each project analyzed) which are presented in Appendix A of the June 1972 progress report of the MIT Transportation Computer Use Group (Ref. 12). A sample project template is included in Appendix F of this report.

### 4.3.3 Computer Use Characteristics Study

The second task was addressed by studying what the MIT group considered to be the most important aspects of a computer system designed to support transportation analysis and planning:

a. Man/machine interaction

b. Software

c. Technical data storage and retrieval

Each of these aspects was divided into finer categories, and the study attempted to isolate the characteristics of each of these categories which would be of the greatest value to various classes of transportation users. The results are presented in the form of user importance matrices which represent a general statement of the significance of various computer system characteristics to various user types.

In the analysis, users were categorized according to their function and their application type. User functions considered were:

a. The programmer, who designs and implements the coding for the application.

b. The ultimate user (typically non-computer specialists, such as transportation planners, researchers, or administration). Such users will probably have minor needs to do some programming.

The classes of applications considered were:

a. Real Time Applications - the operation of devices such as cockpit simulators and driver road simulators, as well as production systems like Dial-a-Ride.

b. Statistical Analysis - the processing of data to obtain certain statistical summaries at the direction of a transportation researcher.

c. System Design Applications - computer tools designed to aid transportation planners in designing particular systems.

Included in this category are facilities such as DODOTRANS that aid planners in predicting the impacts of proposed actions and other tools such as mathematical programming which assist the user in searching through a potential solution space.

d. Simulations - an important class of computer application involving the use of an automated model to study a real world situation. This kind of analysis can also be important in real time and design applications and as an independent research tool.

e. Administration - the use of a system to assist the administration of TSC projects. Included in this category are standard applications, such as accounting and payroll production, as well as more sophisticated applications such as real time interrogation of data describing the progress of work at the Center.

The two user functions coupled with the five application types yield ten user types. The importance of various computer system characteristics to each of these user types was analyzed and compiled in importance matrices, which were the basic output of the three system characteristic studies (Tables 4-3, 4-4, 4-5). The definitions of the computer system characteristics and the support for the importance of each assigned to each user type are contained in Appendix G.

### 4.3.4 TSC Computation Demand Projections

The third task, which was quite specific in comparison to the general purpose nature of Tasks 1 and 2, was the projection of the qualitative and quantitative computer demands of TSC in FY 77. It is important to stress that this study addressed only what the FY 77 needs of TSC will be and not how these needs should be satisfied. The results of the study should be inputs to policy decisions and system design studies.

As shown in the macro-flow diagram of Figure 4-1, the process by which FY 77 TSC needs were projected builds upon the first two

TABLE 4-3 MAN/MACHINE INTERACTION: USER REQUIREMENTS

| User Types | | Interaction Mode | | | | Input Media | | | | | | | Output Media | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Analog | | Graphic | | | | | Analog | | Graphic | | | |
| Application | Function | Batch | Communication | Conversation | Real-Time | Keyboard | Human | Mechanical | Tablet | Digitizer | Joy-Stick, Mouse | High Volume | Alphanumeric | Human | Mechanical | Static | Dynamic | Hard Copy | High Volume |
| Real Time | Programmer | 1 | 1 | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 2 | 3 | 2 | 3 | 3 | 1 | 3 | 2 | 3 |
| | User | 1 | 1 | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 2 | 1 | 2 | 3 | 3 | 1 | 3 | 2 | 1 |
| Statistical Analysis | Programmer | 2 | 2 | 2 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 3 | 3 | 1 | 1 | 3 | 1 | 3 | 3 |
| | User | 3 | 2 | 3 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 3 | 1 | 3 | 2 |
| Design | Programmer | 2 | 2 | 3 | 2 | 3 | 1 | 1 | 1 | 3 | 2 | 3 | 3 | 1 | 1 | 2 | 1 | 3 | 3 |
| | User | 3 | 1 | 3 | 2 | 3 | 1 | 1 | 1 | 3 | 2 | 3 | 3 | 1 | 1 | 2 | 1 | 3 | 3 |
| Simulation | Programmer | 2 | 2 | 3 | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 3 | 3 | 2 | 2 | 1 | 3 | 2 | 3 |
| | User | 2 | 2 | 2 | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 1 | 3 | 2 | 2 |
| Administration | Programmer | 2 | 2 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 2 | 1 | 3 | 2 |
| | User | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 2 | 1 | 3 | 3 |

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TABLE 4-4 SOFTWARE: USER REQUIREMENTS

| User Types | | Programmer Languages | | | | | | | System Support | | | | | | | User-Oriented Language and System Support | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Applications | | | | File System | | | Utilities | | | | | |
| Application | Function | Ease of Use | Data Structures | Extensibility | Multi-Tasking | Recursive Ability | Simulation | Real Time | Virtual Memory | Meta Systems | Sharing | Control | Protection | Standard | Transportation | Problem-Oriented Languages | Timesharing | Integration | Utilities |
| Real Time | Programmer | 3 | 3 | 2 | 3 | 3 | 1 | 3 | 3 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 3 | 2 |
| | User | 2 | 2 | 1 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 3 | 3 |
| Statistical Analysis | Programmer | 3 | 3 | 2 | 1 | 2 | 2 | 1 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 |
| | User | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 2 | 3 | 1 | 1 | 2 | 3 |
| Design | Programmer | 3 | 3 | 2 | 1 | 2 | 2 | 1 | 3 | 3 | 2 | 1 | 1 | 2 | 1 | 3 | 1 | 3 | 2 |
| | User | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 | 3 | 3 |
| Simulation | Programmer | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 1 | 3 | 2 | 3 | 2 |
| | User | 2 | 2 | 1 | 1 | 1 | 3 | 2 | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 3 | 2 | 2 | 3 |
| Administration | Programmer | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 3 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 2 |
| | User | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 3 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | 3 |

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TABLE 4-5 TECHNICAL DATA STORAGE AND RETRIEVAL: USER REQUIREMENTS

| | | Data Management Parameters | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Modes of User Access | | | | Associative Facilities | | Storage Structures | | Access Control | |
| | | Language | | Access Quanta | | | | | | | |
| Application | Self Function | Self Contained | Host Lang Extension | Batch | Unit Trans-action | Within Row | Between Rows | Static | Dynamic | Read | Write |
| Real Time | Programmer | 1 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 1 | 3 |
| | User | 1 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 1 | 3 |
| Statis-tical Analy-sis | Programmer | 2 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 1 | 3 |
| | User | 2 | 2 | 3 | 1 | 3 | 3 | 3 | 1 | 1 | 3 |
| Design | Programmer | 1 | 3 | 2 | 3 | 3 | 3 | 2 | 3 | 1 | 3 |
| | User | 1 | 3 | 2 | 2 | 3 | 3 | 2 | 3 | 1 | 3 |
| Simu-lation | Programmer | 1 | 3 | 1 | 3 | 3 | 3 | 2 | 2 | 1 | 3 |
| | User | 2 | 3 | 1 | 2 | 3 | 3 | 2 | 2 | 1 | 3 |
| Ad-minis-tration | Programmer | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |
| | User | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 |

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1 2 3

Less Important More Important

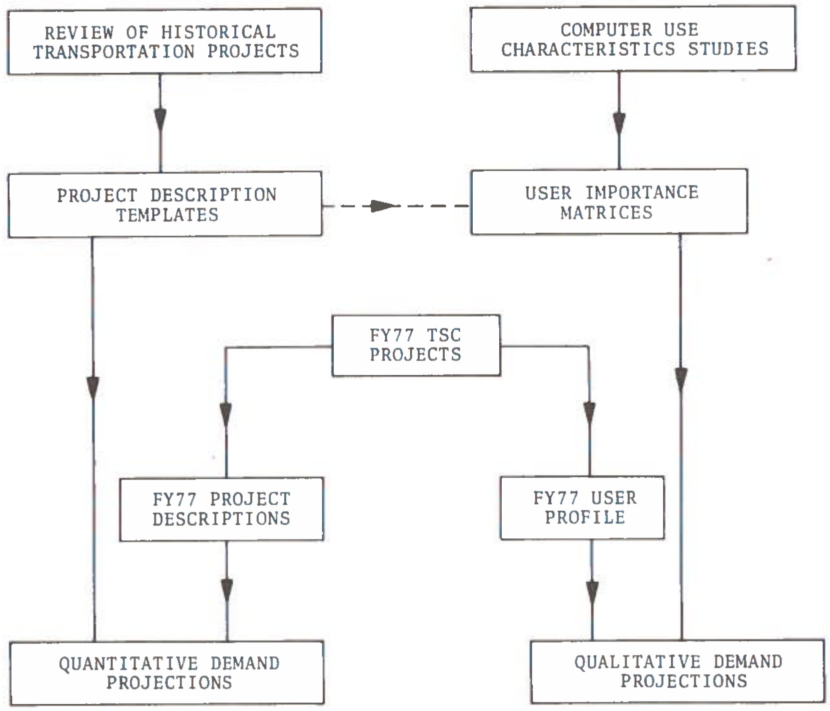


Figure 4-1 Projection Methodology

tasks performed by MIT and the projected FY 77 program mix developed at TSC. The process required three basic inputs:

1. The historical project templates described in Section 4.3.2.
2. The user importance matrices described in Section 4.3.3.
3. The activities of TSC in FY 77 as described in Section 4.2.

Project profiles of 20 projects which represent the activities of TSC in FY 77 were prepared for the MIT group. These profiles included program data forms, which delineated the functional characteristics of the 20 projects (see Section 4.2), and written project descriptions.

The projection technique was designed to produce first order approximations of the quantitative and qualitative computation demands of TSC in FY 77. More precise results were precluded by uncertainties in the input data regarding the FY 77 projects. These uncertainties were of three types:

1. The exact project mix in FY 77 is uncertain. Clearly, changes in the number of projects and the size of projects would change quantitative projections.

2. Definition of the 20 projects was not precise. While general descriptions of these projects were available, the projection of the exact nature of the technical scope of these projects five years hence was made with uncertainty. For example, since many of these projects were of a research and development nature, the levels of effort in FY 77 are clearly dependent on the accomplishments up to that time.

3. The precise skill mixes needed for the various projects were difficult to project, and hence the user profile in FY 77 was subject to various uncertainties.

With the above in mind, it would be inappropriate to interpret the individual project needs as precise, since particular projects may change in nature. If, however, the assumption is made that future TSC activities were represented in the aggregate by the projected FY 77 project mix and skill mix, then the results produced by the technique are meaningful.

The demands projected for FY 77 fall into two basic categories:

1. "Qualitative Demands" - These are parameters that relate to the computational environment provided and typically are difficult to express numerically. These demands are based on the computer system characteristics found important to transportation users in the computer use characteristics study.

2. "Quantitative Demands" - These are parameters that can be expressed numerically:[1]

   a. CPU time (hours)

   b. Terminal usage (hours)

---

[1]Preliminary work has been completed on primary memory and secondary storage and is described in Appendix D of Reference 12.

4.3.4.1 Qualitative Demands - The qualitative demands were determined by combining the estimated percentage of the Center's FY 77 computer budget allocated to each of the ten user types - the user type/budget allocation vector - with the importance matrices produced for the three computer system characteristics studies. This process translated a general statement of what constitutes an important characteristic, represented by the importance matrices, into a specification particular to the needs of TSC. One difficulty with accomplishing this was the nature of the importance measure. Specifically, importance was measured on an ordinal scale which shows a relative ranking but not a quantitative indication of absolute significance. That is, an importance score of 3 indicated that the system parameter involved was more important than one with a score of 1 but not necessarily 3 times as important. For this reason, it was not meaningful to gauge the importance of the characteristic by forming the product of an importance matrix and the user type/budget allocation vector. That procedure would have placed an implicit cardinal meaning on the ordinal measures. Instead, a method more in keeping with the intuitive nature of the importance measures was employed. This technique attributed to each characteristic a score from 1 to 4 representing the significance of that qualitative property to TSC users. This significance was judged by the percentage of the budget allocated to users for which the function was of importance 3, 2 and 1. The results of this operation are shown in Table 4-6.

Examination of these rankings indicates an important trend. Note the types of software included in the most important category; two of the four characteristics shown, simulation aids and problem-oriented languages, are specifically concerned with user convenience. Because of the dominant position of three user types - statistical analysis, design, and simulation users - in TSC's projected FY 77 skill mix, system characteristics are strongly oriented toward user analysis aids and away from real time control and programming conveniences. This conclusion is clearly dependent on the accuracy of the assignments in the importance matrices. The trend is so overwhelming, however, that it is unlikely to be reversed by minor modifications.

TABLE 4-6 RANKING OF CHARACTERISTICS' IMPORTANCE IN TSC

| | MAN/MACHINE INTERACTION | SOFTWARE | DATA MANAGEMENT |
|---|---|---|---|
| 4 | Interaction Mode<br>    Batch<br>    Conversation<br>Input Media<br>    Keyboard<br>    High Volume<br>Output Media<br>    Alphanumeric<br>    Graphic-Hard Copy<br>    High Volume | Programmer Languages<br>    Applications-Simulation<br>System Support<br>    Meta Systems<br>    File System-Sharing<br>User-Oriented Support<br>    Problem Oriented Languages<br>    Integration<br>    Utilities | Modes of User Access<br>    Language-Host Language Extension<br>    Access Quanta-Unit Transactions<br>Associative Facilities<br>    Within Row<br>    Between Rows<br>Storage Structures<br>    Static<br>    Dynamic<br>Access Control<br>    Write |
| 3 | Interaction Mode<br>    Communication<br>Input Media<br>    Graphic-Digitizer<br>    Graphic-Joystick, Mouse<br>Output Media<br>    Graphic-Static<br>    Graphic-Dynamic | Programmer Languages<br>    Ease of Use<br>    Data Structures<br>System Support<br>    Virtual Memory<br>    File System-Control<br>    Utilities-Standard<br>    Utilities-Transportation<br>User-Oriented Support<br>    Timesharing | Modes of User Access<br>    Language-Self Contained<br>    Access Quanta-Batch |
| 2 | Interaction Mode<br>    Real Time<br>Input Media<br>    Analog-Human<br>    Analog-Mechanical<br>    Graphic-Tablet<br>Output Media<br>    Analog-Human<br>    Analog-Mechanical | Programmer Languages<br>    Multi-Tasking<br>    Recursive Ability<br>    Applications-Real Time | |
| 1 | | Programmer Languages<br>    Extensibility<br>System Support<br>    File System-Protection | Access Control<br>    Read |

4.3.4.2 Quantitative Demands - The quantitative computer system characteristics estimated were:

a. CPU Time - the amount of CPU time demanded in-house during FY 77 by TSC projects. For purposes of comparison, the object machine was the CDC 6600. Note that these estimates did not include so-called system time, but only that directly utilized by the projects. In particular, system CPU time consumed in supporting remote job entry or interactive timesharing systems was not included.

b. Terminal Hours - the number of terminal-connect hours used by TSC in FY 77. As will be seen, this was directly dependent on the CPU estimates.

For each FY 77 TSC program, a low and high value of its computer budget/in-house budget ratio (CB/B) was estimated, reflecting uncertainty in the actual nature of the projects. This in turn yielded low and high estimates of CPU time.

The aggregation of overall TSC requirements was performed simply by adding the individual project's low and high estimates. Hence, a low and high overall estimate was obtained. For computational efficiency, CB/B estimates for only the eight largest projects were made, these representing about 75 percent of the total budget (see Table 4-7). The total CPU time was then scaled proportionally up to the full budget. The accuracy of this approximation was checked by scaling the sum of the estimates for the six largest projects (65 percent of budget) and for the 7 largest projects (70 percent of budget) to the full budget level. The results differed from those obtained using the 8 largest projects by less than 1 percent.

When all projects were considered, a range of 3,800-10,500 CDC 6600 hours was projected (Table 4-8). Also shown is the CPU use for a budget and program mix which do not include the two largest projects, demonstrating the impact of large projects on the magnitude of computer use. It is emphasized that these estimates do not include system overhead time.

TABLE 4-7 EIGHT LARGEST FY77 TSC PROJECTS
(RANKED BY IN-HOUSE BUDGET)

| Rank | Project | FY77 In-House Budget (Millions) | Percent of Total FY77 In-House Budget | Cumulative FY77 In-House Budget (Millions) | Cumulative Percent | Estimated CB/B |
|---|---|---|---|---|---|---|
| 1 | Dual Mode | 7.6 | 17.4 | 7.6 | 17.4 | .10 - .12 |
| 2 | Urban Congestion | 6.7 | 15.2 | 14.3 | 32.6 | .12 - .50 |
| 3 | V/Stol | 4.7 | 10.7 | 19.0 | 43.3 | .10 - .50 |
| 4 | 4Gats | 4.7 | 10.7 | 23.7 | 54.0 | .10 - .12 |
| 5 | Balance | 2.7 | 6.2 | 26.4 | 60.2 | .10 - .20 |
| 6 | Rail Efficiency | 2.2 | 5.1 | 28.6 | 65.3 | .10 - .50 |
| 7 | Near Term | 2.2 | 5.1 | 30.8 | 70.4 | .10 - .12 |
| 8 | Intersection Improvement | 2.2 | 4.9 | 33.0 | 75.3 | .10 - .17 |

TABLE 4-8 PROJECTED FY 77 TSC CPU USE[1]

| | CPU Hours (CDC 6600 Base) | |
|---|---|---|
| | Low | High |
| All Projects (Budget = $43.9 million) | 3,800 | 10,500 |
| All projects Except Dual Mode (Budget = $36.3 million) | 3,200 | 10,200 |
| All Projects Except Dual Mode, Urban Congestion (Budget = $29.6 million) | 2,500 | 6,900 |

[1] These figures do not include system overhead, estimated to be in the order of 30 percent.

The basis for terminal hours to be needed at TSC in interactive or timesharing mode was two observations taken from an existing large-scale system at MIT which has a job mix roughly similar to that expected for TSC (scientific and research computing):

a. For every minute of computing actually performed on an interactive system, 30 minutes are spent at the terminal;

b. 40 percent of CPU hours used at the MIT Information Processing Center are used in interactive computing.

Using these figures with the projected TSC CPU usage, the following range of terminal hours was projected:

3,810 hours X .40 X 30 = 45,600 terminal hours or 23 terminal years (8 hour shifts);

10,500 hours X .40 X 30 = 126,000 terminal hours or 63 terminal years (8 hour shifts).

Clearly, these estimates were quite sensitive to the assumptions on the ratio of terminal time to CPU time and the percent of time used interactively. This analysis was intended simply to give a feel for the terminal time required.

The quantitative results can be summarized as:

| | |
|---|---|
| CPU time | 3,800 - 10,500 hours (CDC 6600 base) |
| Terminal hours | 23 - 63 terminal-years (8 hour shifts) |

The projection technique was validated using the FY 72 projects as a base. A range of 800-2,300 CPU hours was projected (after eliminating some major projects which used zero computer time) which was comparable to the 600-1100 hours actually used (Ref. 8). That the actual range is at the lower end of the projected range implies a minimum level of computer utilization compared to that used by historical projects.

The ratio of computer budget to in-house budget for FY 77 was projected to rise to between .10 and .28 (as compared with an actual CB/B of .08 in FY 72 (Ref. 8). Computer use was thus projected to expand 4 - 10 times by FY 77 reflecting:

a. A doubling of the in-house budget;

b. A softening of the project mix;

c. And more reliance on computers in the solution of transportation problems.

### 4.3.5 Conclusions

The Computational Demand Study had three aims:

1. To gain insight into the manner in which computers have been utilized by transportation projects - addressed by studying seven widely varied projects in depth. The templates developed are a useful source document for those interested in the magnitude and nature of computer utilization on various kinds of transportation studies.

2. To study the computer needs of various user types - addressed by (a) choosing several important aspects of computer systems, (b) sub-parameterizing these areas, and (c) isolating the needs of various user classes relative to these sub-areas. The main inputs were the data gathered from historical projects and the experience of the MIT authors on a variety of transportation and computer projects. The results of this study, embodied in the user importance matrices, catalog and organize one group's perception of the computer needs of various transportation users.

3. To project the computational demands of TSC in FY 77 - Both quantitative and qualitative demands were considered. The results were directly dependent on the FY 77 TSC projects used in the analysis and the understanding of what the projects will entail from a technical viewpoint.

The following general conclusions can be drawn:

1. The qualitative needs of TSC in FY 77 are biased toward assisting user analysis rather than real-time monitoring and control or programmer aids. This indicates that tools

such as simulation languages and problem-oriented languages should be emphasized in system design. These results are dependent on assumptions about the relative significance of each user type to the proposed FY 77 projects, but it is unlikely that the weightings could be shifted enough to reverse the basic conclusions.

2. The computer demands at TSC in FY 77 will rise quite substantially over the FY 72 use. An increase in computer use of four to ten times was projected.

3. Very large projects impact the type and magnitude of computer use quite substantially.

This analysis has isolated TSC's computer demands. The next step is to decide to what degree these demands are to be met. That is, the results presented herein should be viewed as input to the design of computer system(s) for TSC in FY 77. This design must explicitly address questions of cost versus potential benefits. Whether a particular computer system feature should be implemented is dependent upon the need for this feature as well as its cost. To borrow from transportation economics methodology, this study has considered computer demand; the next step, that of design, must consider the means and extent of supply.

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APPENDICES

# APPENDIX A. TSC COMPUTER USER SURVEY

## A.1 INTRODUCTION

In April 1972, the TASF Program Office (TPO) circulated a Computer User Survey to all TSC division chiefs. The purpose of the survey was twofold:

1. To obtain computer system requirement projections which could both indicate potential trends and identify specific requirements that might not otherwise be considered in forecasting TSC's FY 77 needs;

2. To establish an interface with the computer system users which would encourage their involvement in the planning process.

The survey mailed to all division chiefs is presented in Figure A-1. Both qualitative and quantitative information was sought. Qualitatively, TPO desired to know what types of future software and hardware would be required to support each division's needs. Quantitatively, TPO wished to determine existing division ADP budgets and the number of division personnel who actually used computer programs or operated ADP equipment. The quantitative results were to be approximations at best; the division personnel completing the survey were asked specifically not to do an involved financial analysis for these questions. The quantitative results were used by TPO only to indicate trends in division and directorate funding.

The results, based on twelve responses to thirteen requests, are summarized below.

## A.2 QUANTITATIVE SURVEY RESULTS

The ADP expenditures for the directorates are presented in Table A-1. ADP expenditures comprise:

1. Division Chief ____________ Organization Code ____________

2. Circle word(s) which describe your division's main function(s):

| | | |
|---|---|---|
| Planning | Research | System Analysis |
| Design | Evaluation | Fabrication |
| Demonstration | Program Control | Other ____________ |

3. Circle program areas in which your division is mainly involved:

| | | |
|---|---|---|
| Safety | Ground Transportation | Multi-modal Transportation |
| Pollution Reduction | Air Transportation | Other |
| Noise Abatement | Marine Transportation | |

4. Expenditures

   a. Estimate your total division expenditures ($) (exclude all IDA's from your division to other divisions and outside contracts)

   FY 71 __________; FY 72 __________; FY 73 __________

   b. Estimate the following ADP expenditures ($) incurred by your division:

      1. Computer Hardware (purchase, operation and maintenance cost)

      FY 71 _________; FY 72 _________; FY 73 _________

      2. Computer Rental (in-house and outside data service cost)

      FY 71 _________; FY 72 _________; FY 73 _________

      3. Computer Software Development (include IDA, job orders, and outside contracts)

      FY 71 _________; FY 72 _________; FY 73 _________

Figure A-1 TASS User Survey

c. In the future do you anticipate that your division ADP expenditure will linearly increase as your total expenditures increase?______________________________
If not, why?______________________________
______________________________

d. In FY 72, what % of your total ADP budget represents expenditures for outside computer service? ________%. Do you foresee outside ADP service expenditure (increasing, decreasing, staying the same) in the future?
__________

5. Manpower

a. Estimate how many "professional" personnel were in your division in:

FY 71 ________; FY 72 ________; FY 73 ________

b. In your estimation, what % of your professional personnel presently run programs on a computer (in-house or outside TSC)?

At least once every two weeks________

At least once a year ________

6. List type of present typical computer software program(s) (e.g. data reduction, modeling (demand, network, etc.), real time simulation, information management, test control, etc.) and size.

| Computer Program Type | Size of Program (if known) (# cards, bits, etc.) |
|---|---|

Figure A-1 TASS User Survey (continued)

7. User Software Needs

a. What types of languages (Fortran, APL, etc.) do you estimate will be required to support your future computer programs?

b. What type of special purpose support (e.g. scientific subroutines, linear programming, statistical analysis packages, etc.) do you estimate will be required to support your future program?

8. User Hardware "Wish List"

Which of the following items, if available at the Center, would be desirable for your division? (For each item below place - "M" (mandatory), "D" (desirable), or "N/A" (not applicable).

| Item | Requirement (M, D, or N/A) |
|---|---|
| a. Job Control | |
| 1. Batch | ________ |
| 2. Remote Batch | ________ |
| 3. Time Sharing | ________ |
| 4. Real Time | ________ |
| b. Peripherals | |
| 1. Alphanumeric Terminal | ________ |
| 2. Graphic Terminal | ________ |
| 3. Plotters | ________ |
| 4. Optical Character Recognition Equip. | ________ |
| 5. Cassette-Cartridge Equipment | ________ |
| 6. Computer Output Microfilm Recorder | ________ |
| 7. Large Screen Display | ________ |

Figure A-1 TASS User Survey (continued)

9. Future Facility Requirements

How do you foresee your future (2-4 years) ADP requirements will be met? (Place - Yes, No, or ? for each item below)

a. In-house Facilities _______

b. Outside TSC Data Service _______

c. Combination of "a" and "b" above _______

d. Purchase own ADP equipment _______

Figure A-1 TASS User Survey (continued)

TABLE A-1 FY 72 ADP FUNDING SUMMARY

| | Directorate | | | | |
|---|---|---|---|---|---|
| | S | P | T | A | Total |
| Financial | | | | | |
| Total In-House Expenditures ($K) | 1,700 | 9,100 | 6,700 | | 17,500 |
| ADP expenditures ($K) + (% of Directorate Total) | | | | | |
| Hardware Purchase | -- | 235 (15%) | 125 (25%) | -- | 360 (10%) |
| Computer Rental | 77 (10%) | 383 (25%) | 120 (20%) | 103 (25%) | 683 (20%) |
| Software Development | 640 (90%) | 1,072 (60%) | 285 (55%) | 286 (75%) | 2,283 (70%) |
| Total | 717 | 1,640 | 530 | 389 | 3,306 |
| % of computer rental expenditure to total in-house funding | 5 | 4 | 2 | -- | 4 |
| % of total ADP expenditures to in-house funding | 40 | 20 | 10 | -- | 20 |
| % of computer rental for out-house computer service | 45 | 25 | 60 | -- | 35 |

TABLE A-1 FY 72 ADP FUNDING SUMMARY (CONTINUED)

| | Directorate | | | | |
|---|---|---|---|---|---|
| | S | P | T | A | Total |
| <u>Personnel</u> | | | | | |
| No. of professionals | 37 | 67 | 141 | -- | 245 |
| % of professionals who | | | | | |
| a. use computer at least once every two weeks | 16% | 13% | 24% | -- | 20% |
| b. use computer at least once a year | 38% | 37% | 48% | | 44% |

1. Equipment purchase;
2. Computer rental; and
3. Software support, operation, and development.

Over 60 percent of TSC's total ADP expenditures in FY 72 were incurred by the Transportation Systems Development Directorate (P). Specifically, the division with the largest reported expenditure for new computer hardware was the Aeronautical Program Office Division (PG); for computer rental, the Aeronautical System Program Division (PG); and for software development, the Systems Analysis Division (SA). In FY 72, the total ADP expenditure was $3.4M, of which 60 percent was incurred for software development.

Approximately 35 percent of computer rental was for outside computer rental services. The small predicted increase in ADP expenditures from FY 72 to FY 73 is a result of the different divisions' difficulty in predicting their future computer workload.

Table A-1 also presents data concerning TSC personnel who use computers. Results of the survey show that of the 245 TSC professionals[1] represented in the responses, approximately 20 percent run programs on a computer at least once every two weeks, while 40 percent run programs at least once a year.

## A.3 QUALITATIVE SURVEY RESULTS

Table A-2 presents a summary of the qualitative data. The numbers in the figure are the responses of the divisions which answered the survey. Note that not all divisions surveyed felt that their future ADP expenditures would at least increase linearly as their total expenditures increase. This result is surprising in that the TSC goal of increased "leverage" in the future years should cause the percentage of ADP expenditures to

[1]The figure of 245 TSC professionals is low due to the fact that not all divisions responded to this particular question.

TABLE A-2 QUALITATIVE SURVEY RESULTS

<u>General</u> (By Division)

| | Yes | No |
|---|---|---|
| 1. Will your division's ADP expenditures at least increase linearly in the future as your total expenditures increase? | 6 | 6 |
| 2. Will your division's outside computer service expenditures decrease in the future | 4 | 4 |
| 3. Will your future computer requirements be satisfied by | | |
| a. in-house service | 10 | -- |
| b. outside computer services | 5 | 2 |
| c. purchasing own equipment | 4 | 4 |

| Software | Qualitative Survey Results |
|---|---|
| 1. General types of software presently being used: | Data reduction,* modeling,* information management, real time simulation test control, administrative support |
| 2. Future computer languages | Fortran,* APL, PL/I, Honeywell DAP, GPSS, Cobal, DAP |

*Indicated heavy use or strong need.

TABLE A-2 QUALITATIVE SURVEY RESULTS (CONTINUED)

Software (Continued)

| | |
|---|---|
| 3. Future special purpose support | Statistical Analysis Package,* linear Programming, CDC programs Rand "Big Mod," Information Retrieval, Business and Scientific Display Graphics, simulation |

Future Computer Needs (by Division

| Item | Expressed Need | | | Expressed No Need | |
|---|---|---|---|---|---|
| | Mandatory | Desirable | % | No Need | % |
| **Mode** | | | | | |
| Batch | 10 | -- | 90% | 1 | 10% |
| Remote Batch | 4 | 4 | 70% | 3 | 30% |
| Time Sharing | 4 | 6 | 90% | 1 | 10% |
| Real Time | 4 | 6 | 90% | 1 | 10% |
| **Equipment** | | | | | |
| Alpha Terminal | 4 | 7 | 100% | -- | 0% |
| Graphic Terminal | 3 | 5 | 70% | 3 | 30% |
| Plotter (x-y) | 5 | 2 | 60% | 4 | 40% |
| Optical Character Recognition | -- | 3 | 25% | 8 | 75% |
| Cassette-Cartridge | -- | 3 | 25% | 8 | 75% |
| Computer Microfilm Output Recorder | 1 | 4 | 50% | 5 | 50% |
| Large Screen Display | 2 | 4 | 60% | 4 | 40% |

*Indicates heavy use or strong need.

total funding to decrease. Four divisions foresee purchasing their own ADP equipment. Table A-2 also presents a list of TSC future hardware needs. The question in the survey was stated in such a way that the "need" for a particular item was expressed in terms of a manditory, desirable, or no need basis. As expected, the need for batch mode operation in the future is quite evident. The survey showed that 70 percent of the divisions surveyed believed that remote batch capabilities would increase their effectiveness. One hundred percent of the divisions felt that an alpha terminal (70 percent with a graphic terminal) used to input or receive data from a computer would be beneficial to their operation.

## A.4 CONCLUSIONS

The results of the survey show that in an absolute sense, the quantitative data are questionable; however, these data were and can be useful in projecting trends in particular divisions' or directorates' ADP expenditures. Second, the divisions as a whole are unable to predict their ADP requirements one year in advance. Absolute quantitative projections for FY 77 requirements cannot be based on the results found in the survey. Third, software development costs now, and most probably in the future, will constitute the greatest percentage of ADP expenditures. Fourth, TSC computer users predict that without modification of the present in-house computer systems, a continued reliance on outside computer services will be necessary.

From a qualitative point of view, the range of software (general purpose, special language) required at TSC in the future is very broad; in work to update the present system or plan a new system, this problem must be studied carefully. Also, many divisions (one-half of those who replied) expect to purchase ADP peripheral equipment.

This survey was intended to be a first step in receiving information from the TSC computer user community on future requirements. As the development of TASS proceeds, new surveys, requiring detailed analysis of individual user requirements will be needed.

# APPENDIX B. FY 73 TSC PROGRAMS

| PPA | Program Title | Funding - $K |
|---|---|---|
| | **Safety** | |
| FA305 | Aircraft Wake Vortices Sensing System | 1000 |
| FA314 | Pilot Warning Indicator | 750 |
| FA320 | Long Range Clear Air Turbulence | 200 |
| HS304 | Crash Survivability | 55 |
| HS303 | Tire Non-Destruction Testing Study | 560 |
| HS302 | Alcohol Research and Testing | 500 |
| OS313 | Air Passenger Transportation Security | 400 |
| RR309 | Human Factors - Railroad Operations | 300 |
| RR301 | Train Control & Operations | 100 |
| RR302 | Grade Crossing Detection | 700 |
| RR303 | Rail & Wheel Flaw Detection | 40 |
| HW301 | Maine Facility | 350 |
| FA322 | Elect. Cardiogram Process. Study | 158 |
| HS305 | Occupant Motion Sensor | 200 |
| HS306 | Alcohol Safety Interlock | 50 |
| HS308 | -- | 385 |
| | | 5750 |
| | **Pollution Reduction** | |
| CG303 | Pollution Control | 200 |
| OS314 | Pollution Control | 150 |
| CG307 | Vessel Emission Monitor & Control | 200 |
| HS301 | Exhaust Emission Study | 120 |
| | | 670 |
| | **Multi-Modal System** | |
| OS301 | R&D Management Support | 200 |
| OS312 | Trans. Sys. Plan. & Oper. Anal. | 869 |
| OS318 | Dual Mode System Prototype Development | 530 |
| OS320 | CIAP Support | 530 |

| PPA | Program Title | Funding - $K |
|---|---|---|
| | Multi-Modal System (Continued) | |
| OS322 | Trans. Environment Impact Technology | 150 |
| OS323 | Analysis & Simulation Planning | 455 |
| OS324 | TRAIS Support | 200 |
| OS325 | Balance | 225 |
| OS326 | Urban Blend | 925 |
| OS327 | IR&D Urban System Analysis | 350 |
| OS329 | Short Haul Study | 350 |
| OS330 | Cargo Data Management | 48 |
| OS331 | Communication & Control | 140 |
| OS332 | University Research | 130 |
| OS397 | IR&D | 650 |
| | | 5750 |
| | Ground Transportation | |
| HW302 | Dallas Corridor Study | 60 |
| UM301 | TACV Technical Support | 973 |
| UM304 | Rail System Supporting Technology | 6500 |
| UM305 | Morgantown Technical Assistance | 285 |
| HW305 | Aerial Film Data | 50 |
| HW308 | Shock Wave Analysis | 50 |
| OS319 | Automobile User Technology | 500 |
| RR307 | Ram Air Cushion System | 65 |
| UM306 | New System Development Engineering | 4100 |
| UM307 | RDM Program Planning Assistance | 50 |
| RR304 | HSGT Communication | 150 |
| RR305 | Power Collection for High Speed Tracked Vehicles | 385 |
| RR312 | Operating Equipment | 440 |
| UM308 | -- | 442 |
| UM305 | PRT | 400 |
| UM310 | Bus AVM | 100 |
| RR313 | R.R. Economic & Planning Management | 50 |
| | | 14580 |

| PPA | Program Title | Funding - $K |
| --- | --- | --- |
| | **Marine Transportation** | |
| OS308 | Maritime Satellite Study | 400 |
| | | 400 |
| | **Noise Abatement** | |
| OS307 | Noise Abatement | 1350 |
| | | 1350 |
| | **Air Transportation** | |
| OS305 | Air Transportation System Concept | 545 |
| FA306 | Flow Control Analysis | 500 |
| FA311 | Satellite Systems | 2000 |
| FA319 | ATCRBS System Study | 1250 |
| FA315 | Visibility Measuring Techniques | 250 |
| FA313 | Data Link | 2200 |
| FA307 | Current ILS | 300 |
| FA309 | Microwave Landing System | 900 |
| FA321 | Ground Guidance & Control | 2750 |
| FA318 | STOL Navigation & ATC Program | 570 |
| OS304 | Advance Air Traffic Control Systems | 5825 |
| FA303 | Future Data Processing | 300 |
| FA323 | Short Haul Air Analysis | 500 |
| FA324 | DABS | 125 |
| FA325 | Digital Data Transfer | 100 |
| OS321 | Satellite Data Link | 200 |
| OS328 | Low Density Air Service | 200 |
| NA312 | T-003 Experiment | 35 |
| NA313 | Photo Image Enhancement | 50 |
| | | 18600 |
| | | 47100 |

# APPENDIX C. COMPUTER SYSTEM DESCRIPTIONS

On-Site Systems - Tables C1-C4 Off-Site Systems - Tables C5-C14

TABLE C-1 THE HONEYWELL FACILITY

| | H-832 | GOTS-516 | TAG-516 |
|---|---|---|---|
| Memory size | 32,768 words | 32,768 words | 16,384 words |
| Word length | 32 bits | 16 bits | 16 bits |
| Cycle time | 1.25 μsec | 1.08 μsec | .96 μsec |
| Aux. Storage | 2 disk drives @ $14x10^6$ chars. | 3 disk drives @ $7x10^6$ chars. | 1 disk drive @ $7x10^6$ chars. |
| Operator console | 2 KSR 35 TTY | 1 ASR 35 TTY | 1 ASR 35 TTY |
| Printer | 300 lpm | - | 300 lpm |
| Card reader | 400 cpm | - | 300 cpm |
| Card punch | - | - | - |
| Mag. tape drives | 2 7-track | connector to one of H-832 drives | 1 7-track |
| Mag. tape deck | - | - | - |
| Paper tape reader | 300 cps | 300 cps | 300 cps |
| Paper tape punch | 110 cps | 110 cps | 110 cps |
| Terminals | - | 5 KSR 35 TTY | - |
| Displays | - | 1 ITT color, 3 IDI, 1 ARDS | 2 VG1's |
| Tablets | - | 1 Sylvania | 1 graphacon 1010A |
| Plotters | - | 1 Calcomp drum plotter | - |

TABLE C-1 THE HONEYWELL FACILITY (CONTINUED)

| | H-832 | GOTS-516 | TAG-516 |
|---|---|---|---|
| Ownership | government owned | government owned | government owned |
| Other equip. | couplers to GOTS and TAG-516s<br>single line controller option to 2400 band data phone | single line controlled<br>multiple line controller for 16 TTY's<br>high level analog input system<br>joystick (not used)<br>Vermont Res Drum (not used) | flying spot scanner (TRIM)<br>switch box |

TABLE C-2 THE HYBRID FACILITY

a. XDS-9300

| | |
|---|---|
| Memory size | 32,768 words |
| Word length | 24 bits |
| Cycle time | 1.75 μsec |
| Aux. storage | 2 million character drum (RAD) |
| Operator console | (2) KSR model 35 TTY's |
| Printer | 1000 lpm |
| Card reader | (1) 400 cpm; (1) 800 cpm |
| Card punch | 300 cpm |
| Mag. tape drives | (4) 7 track drives |
| Mag. tape deck | - |
| Paper tape reader | - |
| Paper tape punch | - |
| Terminals | - |
| Displays | XDS 9185 scope w/light pen |
| Tablets | - |
| Plotters | - |
| Ownership | leased from XDS (purchase under negotiation) |
| Other equip. | hybrid interface: 40 D/A lines<br>40 A/D lines<br>16 D/A test lines<br>16 A/D test lines<br>10 interrupt lines |

TABLE C-2 THE HYBRID FACILITY (CONTINUED)

b. Beckman 2200 Analog Computer

Computing Components

120 Operational Amplifiers (72 can be integrators)
32 Summers
240 Servo Set Pots
12 Function Generators
48 Comparators
3 Rate Resolvers
16 Limiters
48 Electronic Switches

Logic Elements

96 Or/Nor Gates
12 One Shots
32 Flip Flops
32 Logic Inverters
4 2-Digit Reset Counters
32 3-Diode Networks
8 4-bit Shift Registers

Other Equipment

2 Eight Channel Strip Recorders

TABLE C-3 THE MULTIMODE SIMULATION FACILITY

| | PDP-10 | DDP-516 |
|---|---|---|
| Memory size | 80,000 words | 32,000 words |
| Word length | 36 bits | 16 bits |
| Cycle time | 1.0 μsec | .96 μsec |
| Aux. storage | 2 fixed head disks (@ 500,000 words) | 2 disk drive ($7.5x10^6$ chars) |
| | 1 disk drive ($5.2x10^6$ words) (second drive on order) | |
| Operator console | 1 KSR 35 TTY | 1 ASR 35 TTY |
| Printer | 1000 lpm | - |
| Card reader | (1200 cpm on order) | - |
| Card punch | - | - |
| Mag. tape drives | 2 7-track | - |
| Mag. tape deck | 8 Dec Tape units | - |
| Paper tape reader | 300 cps | 300 cps |
| Paper tape punch | 50 cps | 110 cps |
| Terminals | 12 ASR&KSR 33; 4 phone (16 lines total) (18 on order) | - |
| Displays | 1 ARDS, 1 DELTA DATA Disp. | 1 Tasker Color Display<br>1 Sanders ATC Console Display<br>1 Sanders 960 Display<br>1 Sanders 930 Display<br>1 Sanders 900 Display Generator |

TABLE C-3 THE MULTIMODE SIMULATION FACILITY (CONTINUED)

| | PDP-10 | DDP-516 |
|---|---|---|
| Plotters | Calcomp model 563 | 1 Sac Graf/Pen Tablet w. stylus<br>1 Track Ball; 1 lightpen; 1 Touch-entry |
| Ownership | government owned | government owned |
| Other equip. | CPU has Flt. pt. hardware fast registers, dual memory protection and relocation.<br>1 techtronic tele-printer (100 chars/sec)<br>RNS-10 Interface to 516 | 128 light function keys |

TABLE C-4 THE CENTRAL FACILITY

| | IBM 7094-II | IBM 360/30 |
|---|---|---|
| Memory size | 32,000 words | 65,000 bytes |
| Word length | 36 bits | 8 bit byte/32 bit word |
| Cycle time | 1.4 μsec | 1.5 μsec |
| Aux. storage | - | 1 2311 disk drive ($7.5 \times 10^6$ chars) |
| Operator console | 7151 model 2 | model 1052 |
| Printer | 716 model 1 | 1000 lpm |
| Card reader | 711 model 2 | 1000 cpm |
| Card punch | - | (model 2540 reader punch) |
| Mag. tape drives | 10 7-track | 2 7-track |
| Mag. tape deck | - | - |
| Paper tape reader | - | 1017 model 2 |
| Paper tape punch | - | 1018 model 8 |
| Terminals | - | - |
| Displays | - | - |
| Tablets | - | - |
| Plotters | - | CALCOMP 835 CRT<br>763 pen<br>110 interface |
| Ownership | government owned | leased from IBM |
| Other equip. | - | - |

TABLE C-5 SMITHSONIAN ASTROPHYSICAL OBSERVATORY

Machine: CDC 6400

Primary Memory Size: 65,536 words

Word Length: 60 bit

Cycle Time: 1 μsec.

Complete Add Time: 1.1 μsec.

Auxiliary Storage:

1. 6603 Disk File - 74 million characters
2. 6638 Disk File - 131 million characters
3. 3853 Disk File - 4 million characters
4. Six seven-track magnetic tape drives
5. One nine-track magnetic tape drive

Access Mode: Batch

Available Software: Fortran (IV, Extended), Cobol, Algol, Simscript

TABLE C-6 CONTROL DATA CORPORATION (CYBERNET)

Machine: CDC 6600

Primary Memory Size: 131,000 words

Word Length: 60 bit

Cycle Time: 1 μsec.

Complete Add Time: 0.3 μsec.

Auxiliary Storage:

1. Disk File - 260 million characters
2. Eight Magnetic Tape Drives

Access Mode: Remote Batch

Available Software: Fortran (II, IV, Extended), Cobol, Basic, Algol, Simscript

## TABLE C-7 MIT

Machine: IBM 360/75

Primary Memory Size: Two million bytes

Word Length: 8 bits/byte

Cycle Time: 0.75 μsec.

Complete Add Time: 0.8 μsec.

Auxiliary Storage:

1. Two 2301 drums
2. Three 2314 disk drives
3. Five nine-track magnetic tape drives
4. One seven-track magnetic tape drive

Access Mode: Batch, Remote Batch, Timesharing

Available Software: Fortran IV

TABLE C-8 MITRE

Machine: IBM 370/155

Primary Memory Size: 1.5 million bytes

Word Length: 8 bits/byte

Cycle Time: 0.115 μsec.

Complete Add Time: 0.115 μsec.

Auxiliary Storage:

1. Fourteen disk drives (IBM 2319 or equivalent)
2. Four nine-track magnetic tape drives
3. One seven-track magnetic tape drive

Access Mode: Remote Batch, Batch, Timesharing

Available Software: Fortran IV, Basic, PL/1, ANS Cobol, BMD (Biomedical Computer Programs), WATFOR, SNOBOL/4, Algol

## TABLE C-9 INTERACTIVE DATA CORPORATION

Machine: IBM 360/67

Primary Memory Size: 512,000 bytes

Word Length: 8 bits/byte

Cycle Time: 0.75 $\mu$sec.

Complete Add Time: 1.3 $\mu$sec.

Auxiliary Storage:

1. Drum - 16 million bytes
2. Disk - 800 million bytes
3. Nine magnetic tape drives (seven and nine track)

Access Mode: Timesharing, Batch

Available Software: Fortran IV, Cobol, PL/I, Basic, Bruin, SNOBOL, APL, AED, Script

TABLE C-10 TYMSHARE, INC.

Machine: XDS 940

Primary Memory Size: 64,000 words

Word Length: 24 bits

Cycle Time: 1.75 μsec.

Complete Add Time: 3.5 μsec.

Auxiliary Storage:

1. Two RAD units - four million characters
2. One disk file - 67 million characters
3. Two seven-track magnetic tape drives

Access Mode: Timesharing

Available Software: Super Fortran, Super Basic

TABLE C-11 FIRST DATA CORPORATION

Machine: DEC PDP-10

Primary Memory Size: 256,000 (user core = 35,000)

Word Length: 36 bit

Cycle Time: 1.0 μsec.

Complete Add Time: 2.5 μsec.

Auxiliary Storage:

1. Two DEC tapes
2. Two nine-track magnetic tape drives
3. One seven-track magnetic tape drive
4. Six disk packs - 150 million characters
5. One drum

Access Mode: Timesharing

Available Software: Fortran, Basic, Cobol, Algol

TABLE C-12 GSA TIME SHARE

Machine: GE 440

Primary Memory Size: 64,000 words

Word Length: 24 bit

Cycle Time: 2.8 μsec.

Complete Add Time: 12.6 μsec.

Auxiliary Storage:

Disk Storage - 90 million characters

Access Mode: Timeshare

Available Software: Fortran, Basic

TABLE C-13 THE COMPUTER COMPANY

Machine: IBM 370/155

Primary Memory Size: 512,000 bytes

Word Length: Eight bits/byte

Cycle Time: 0.115 μsec.

Complete Add Time: 0.115 μsec.

Auxilariy Storage:

1. Sixteen Memorex 660 Disk Drives
2. Five Magnetic Tape Drives

Access Mode: Timesharing

Available Software: APL

TABLE C-14 CONTROL DATA CORPORATION (CYBERNET)

Machine: CDC 6400

Primary Memory Size: 131,000 words

Word Length: 60 bit

Cycle Time: 1.0 μsec.

Complete Add Time: 1.1 μsec.

Auxiliary Storage:

1. Six seven-track tape drives
2. One disk file - 167 million characters (permanent)
3. Four disk file - 32 million characters (removable)

Access Mode: Timesharing

Available Software: Fortran (II, IV, Extended), Basic, Cobol, Algol, Simscript

# APPENDIX D. FY 77 TSC PROGRAM MIX

## D.1 CURRENT PROGRAMS EXTENDING INTO FY 77

A. Marine

1. Navigation (Aids to) - Decrease harbor congestion and increase marine traffic efficiency and safety by such actions as defining and determining requirements for marine traffic navigation and control systems. This program will be initiated at Center in FY 73. TSC will provide planning, system analysis and design support to the Coast Guard.

B. Pollution

None

C. Noise Reduction

None

D. Safety

E. Air Transportation

1. Advanced Air Traffic Management Systems - Develop long-range plans for the future Air Traffic Control Systems as dictated by possible future air saturation and high operation and maintenance costs of currently planned systems by such actions as defining a Fourth Generation Air Traffic Control System and advancing air traffic control technology. This program was initiated at the Center in FY 71 under OST sponsorship. TSC's role in this program is and will be in the program management area with emphasis in system analysis, design, and system evaluation.

2. Future Data Processing - Develop advanced computer architectures to accommodate future beacon and satellite data systems which will be used in advanced air traffic control and air navigation systems by such action as making trade-off analysis for different approaches to high speed air traffic control data processing, conducting advanced technology exploration and designing processing networks which will meet the requirements for future air traffic control systems. This program was initiated at the Center in FY 71 under FAA sponsorship. TSC is and will be providing support in the research, design and evaluation areas.

3. Ground Guidance and Control - Generation of automatic ground traffic control system for major airports by such action as the design and development of local area autonomous controllers and ground surveillance radar. This program was started at the Center in FY 72 under the sponsorship of FAA. TSC is and will be providing support in the system analysis, design, evaluation and demonstration areas of the program.

4. Microwave Landing System - Provide line and task management support to the FAA in the development of a microwave landing system. This program was initiated at TSC in FY 71. Besides providing program management support, TSC will be involved in the system analysis, design and evaluation areas.

5. Satellite System - Develop future satellite-aircraft avionics and advanced aircraft communication and navigation equipment technology for the Aeronautical Satellite Air Traffic Control System

by such action as supporting the FAA effort in the overall design of an aeronautical satellite system for an advanced air traffic control system enroute and over ocean air traffic. This program began at the Center in FY 71. TSC is and will be involved in the research, system analysis and design areas.

F. Multi-Modal Transportation

1. Dual Mode - Develop a transit vehicle capable of operating both on highways under manual control and for specifically equipped guideways under automatic computer control by such actions as defining system specifications, developing system software, testing critical technology, preparing a long range technical development program, and designing a public demonstration of first generation technology. This program was started in FY 72 at the Center with funding provided by OST, FHWA, UMTA and FRA. TSC's function in the program is and will be in the program management area with emphasis in system analysis, design, evaluation and system demonstration.

G. Ground Transportation

1. Rail System Support Technology - Provide System Manager support for the UMTA Rail Supporting Technology Program by such actions as developing the UMTA portion of the Pueblo test facility, conducting tests and analyzing test results. This program started at the Center in FY 71. Besides providing system management support, TSC is and will be providing support in the design, evaluation and demonstration areas.

## D.2 NEW PROGRAMS

### A. Marine Transportation

1. Vessel Traffic Systems - Reduce maritime traffic accidents and the attendant loss of life, property and ecological damage by 60 percent by 1980 by such actions as implementation of traffic separation procedures, navigation aids, centralized communications, traffic coordination centers and shore-based radar surveillance with selective vessel tracking and large scale displays of traffic movement. TSC foresees its main role in this USCG program in the system analysis and design areas.

### B. Pollution Reduction

1. Surface Propulsion - By 1980, reduce the energy demands of surface transportation vehicles and systems for fossil fuels by 10 percent while maintaining low air pollution and noise emissions by such actions as developing advanced batteries for electrically powered vehicles, developing techniques to increase efficiency of electric power conditioning, developing efficient motors and controls for vehicles using wayside power, evaluating novel fuels for future vehicles, and improving efficiency of heat engines. TSC forsees its function in this program in the research and design areas.

### C. Noise Abatement

1. Airport Noise - Provide significant improvement in the airport community noise environment and simultaneously increase capacity at existing airports by reducing the noise levels from individual aircraft by 4-20 EPNdB by 1976 by such actions as

developing and implementing new aircraft operational procedures, augmenting research and development leading to retrofitting of existing aircraft with acoustically treated engine installation, developing quieter propulsion systems for future aircraft, and pledging support to accelerate replacement of existing aircraft with quieter new technology aircraft. TSC foresees its role in this FAA program in the research and systems analysis areas.

D. Safety

1. Rail-Highway Intersection Improvement Program - Reduce by 50 percent the number of deaths and injuries due to rail-highway grade crossing accidents by such actions as upgrading, eliminating or separating 50,000 rail-highway intersections. TSC foresees its role in this FRA and FHWA program in the design and evaluation areas.

2. Emergency Medical Services - On a nationwide basis, reduce both mortality and morbidity among the emergency patient population by 20 percent within three years and reduce deaths and hospital days in all transport mode post crash injuries by 30 percent within five years by such actions as establishing specifications for national EMS, promoting, as a new career category, "The Emergency Medical Technician-Ambulance" leading to the physician's assistant, pressing for each state establishing legislation regulating emergency ambulance service in both its business and professional aspects and bringing to bear proper coordination of Federal, state and local resources dedicated to a recognized objective. TSC foresees its role in this program in the planning and system analysis areas.

E. Air Transportation

1. Advanced Aircraft Technology - Develop U.S. aircraft superior in economics and performance to foreign aircraft for the 1980's by such actions as undertaking a comprehensive program to develop technology for advanced long-haul transport aircraft both subsonic and supersonic, including quiet engines for supersonic transports. TSC foresees its function in this FAA program in the research area.

2. V/STOL - Short term: establish the potential of V/STOL to improve aviation system productivity along with market and environmental acceptability. Long term: multi-fold improvement in short-haul aviation system productivity and reduction in aviation short-haul door-to-door travel time by 25 percent. World leadership in aviation technology and sales by such actions as performing market demonstrations, developing quiet STOL engine and flight testing experimental research vehicle. TSC foresees its role in this FAA program in the planning, research and evaluation areas.

F. Multi-Modal Transportation

1. Northeast Corridor Highway Performance Improvement Pilot Program - Prevent expected 35 percent deterioration in average speed of Northeast Corridor intercity travel and avoid a 60 percent increase in peak day trip. Increase safety by such actions as implementation of a real time highway information system, additional short bypasses and interchanges to increase connectivity

of present highway network, and additional short highway sections necessary to establish an alternative spinal route. TSC anticipates its main role in this FHWA program to be in the Systems Analysis, Design, and Evaluation areas.

G. Ground Transportation

1. Bicentennial Rail Improvement - Eliminate passenger transportation problems in the densely populated Northeast Corridor, provide major focus for the 1976 bicentennial celebration serving the original thirteen colonies, and pilot a program for future modernization and revitalization of U.S. rail industry by such actions as upgrading the rail system along the eastern seaboard from Boston to Atlanta and Miami to provide high speed passenger and containerized freight services. TSC foresees its role in this program in the program management, system analysis and evaluation areas.

2. Federal Freight Railroad Initiative - Increase national productivity by reducing interurban (rail/track) goods distribution costs by 25 percent by 1980 within the context of our privately owned and operated rail systems by such actions as railroad modernization (upgrade track and car fleet, freight car scheduling and control system implementation, signals and communications improvements, electrification), railroad relocation (relocation of urban rail facilities, intermodal terminal development), and regulatory modernization. TSC foresees its role in this FRA program in the planning and system analysis areas.

3. Near Term Improvement in Mass Transit - Decrease private autos on urban streets by 25 percent by offering improved, convenient, safe and frequent mass transportation by such actions as massive

replacement and augmentation of the nation's bus fleet, replacement of rail cars with advanced concept cars, modernization of urban rapid transit, commuter rail and light rail stations, demonstration of three large demand responsive (Dial-a-Ride) systems followed by evaluation and decision concerning national program of Dial-a-Ride installation and coordination and integration of above. TSC foresees its function in this UMTA program in the program management area with emphasis in the planning, system analysis, evaluation and demonstration stages of the project.

4. Personal Rapid Transit System - Install and operate a large scale, high capacity urban personal rapid transit system by 1976, by such actions as construction technology and hardware subsystem research, urban site selection, transportation system planning, design system characteristics, fabrication and installation of 30-50 mile system, and operation and evaluation in public service. TSC foresees its role in this UMTA program in the program management area with emphasis in the planning, system analysis, design and demonstration stages.

5. Tracked Levitated Vehicle (TLV) - Establish the feasibility, desirability and applicability of intercity high speed tracked levitated vehicle systems by such actions as developing and demonstrating within three years a first generation (150 mph) TLV and accelerating the TLV research for 300 mph system for 1976 Northeast Corridor investment decisions. TSC foresees its function in this FRA program in the program management area with emphasis in the research, system analysis, design, evaluation and demonstration stages of the program.

6. <u>Balance</u> - Assure the establishment of balanced transportation systems in the future which will provide the greatest benefit at the least cost. TSC foresees its role in this OST program in the planning and research areas.

7. <u>Reduction of Tunnel Costs</u> - Reduce the cost of tunnel construction by at least 30 percent by 1980, by such actions as conducting systems analysis to pinpoint short term improvement opportunities in tunneling, developing the supporting technology for tunneling processes, and developing new tunneling construction systems and demonstrating them. TSC foresees its role in this OST program in the research, systems analysis, design and evaluation areas.

8. <u>Urban Congestion</u> - Decrease overall travel time during rush hour by 25 percent in 50 urban areas by 1980 by improving traffic flow by such actions as implementing computerized traffic light controls, installing ramp metering with bus priority on freeways, allocating 10-20 percent of existing lanes to buses, and implementing bus command and control with priority traffic lights. TSC foresees its function in this UMTA and FHWA program in the program management area with emphasis in the systems analysis, design, evaluation and demonstration areas.

# APPENDIX E. DEFINITION OF PROGRAM FUNCTIONS

## E.1 PLANNING

Program planning is the establishment of future goals and the formulation of the general approach toward achieving these goals. The programs may be an urban planning project, a nation-wide transportation network, or other large systems. Planning is done on both an individual basis and as a group or team effort. A team of people is needed to bring the spectrum of expertise required to deal with massive, complicated systems. The inter-disciplinary nature of the working environment forces special attention to be placed on intra-group communications.

Transportation planning involves many complex variables, such as social economic impact forecast, technological forecast, demand and supply predictions, and land use and urban planning.

## E.2 RESEARCH

Basic and applied research is required in many programs. Research in human behavior, modal split analysis and transportation technology is mandatory to the development of a balanced transportation system that can provide clean, efficient and low cost systems. Exploration of potential systems must be carried forth to insure that the best possible options are available for use by the transportation analyst and designer. The basic and applied research necessary to insure technically feasible transportation programs require access to a wide library service in which the most current thinking on a particular subject can be obtained without large delays for searches, copying, etc. With this information and information concerning current and projected systems, the researchers can address specific problems such as nuclear powered systems, magnetic suspension devices, effects of transportation on urban decay, etc.

## E.3 ANALYSIS

Systems analysis is understanding, evaluating, conceiving, and/or improving transportation systems. The systems analyst evaluates current and proposed transportation systems through modeling and the statistical analysis of data. The systems analyst works in advanced air traffic control, new urban transportation systems, and environmental compatibility determination of transportation systems.

## E.4 DESIGN

Systems design is based on the examination of the transportation objectives, policies and goals that have been generally determined during the systems analysis phase. This includes the design of the necessary subsystems and components for optimum effectiveness and efficiency.

The major factors that must be balanced to obtain optimum benefits to the community, state, and Federal Government are the transport systems' cost, performance, reliability, maintainability, and efficiency.

## E.5 EVALUATION

Systems evaluation is the evaluation of concepts, systems, subsystems and components. The test engineer, in performing evaluation tasks, formulates the testing plan, the parameters to be measured and the test acceptance criteria, as well as manages the performance of the actual test. System evaluation requires that a number of skills be used which are independent of the item to be tested as well as general knowledge of the engineering field which produced the sample for testing.

## E.6 FABRICATION

Fabrication is the conversion of a system design to hardware and software. Fabrication of transportation systems within the DOT is primarily limited to prototypes and the establishment of production techniques that lead to more cost-effective systems. Production costs represent a significant percentage of the cost of a major transportation system; improved technique of manufacturing can result in significant cost savings.

## E.7 DEMONSTRATION

Demonstrations leading to an operating system are the final step in accomplishing a program. The demonstration involves hardware that is either placed in an operational environment or demonstrated in a lab environment. Feedback of system data to the analysts and designers from these demonstrations is mandatory. Sensor implementation and data handling are prime skills involved in the demonstration in which a concept or procedure must be proven.

## APPENDIX F. SAMPLE PROJECT EVALUATION TEMPLATE

### PROJECT EVALUATION TEMPLATE

Project Name: Bus Dispatching

### F.1 STAGE ONE: GENERAL PROJECT CHARACTERISTICS

A. Project Description

1. General project purpose

   ______Basic research

   ______Software Development

   ______Production use of existing software

   __x__Other: New Transportation System Development

2. Project Costs

   Total cost: $1,500,000

   Computer time cost: $180,000

3. Number of computer jobs: __________

4. Average computer cost per job: ______

5. Program development vs. production runs

   Development 98 percent

   Production 2 percent

6. Additional project description:

   In the description of a project as large in both effort and time span as bus dispatching, a distinction between available, desirable, and mandatory features had to be made when filling in boxes of the Project Evaluation Template. In addition, the actual project did not go through all the phases described (in particular, phase III never existed and phase II was performed in less than ideal financial conditions). Entries for phase I all reflect available features which were used. Entries for phase II reflect features which were used with the following exceptions: multiprocessing, dedicated machines, and back-up machines though mandatory in the description of (an ideal) phase II were neither available nor used. It might appear that there is a contradiction to say a mandatory feature was not used; the actual phase II was performed in a fashion barely acceptable due to extreme budgetary constraints which developed over time. It is unlikely that a project would be begun with the anticipation of performing phase II as it was in fact done.

B. Software

List all major software systems used during the course of the project, the source of the system, and the estimated percentage usage of each. System sources can be indicated using the following code:

M: Basic manufacturer support
S: Basic service bureau support
F: Developed elsewhere, available at no charge
P: Developed elsewhere, available with some charge (proprietary)
IP: Developed inhouse, prior to this project
ID: Developed inhouse, during this project.

(Use additional pages as necessary)

PROJECT EVALUATION TEMPLATE

Project Name: Bus Dispatching

| SOFTWARE SYSTEM | SOURCE | PERCENTAGE OF USE |
|---|---|---|
| CP/67 | M | 90% |
| CMS | M | 70 |
| DOS | M | 15 |
| OS | M | 15 |
| BTAM | M | 15 |
| FORTRAN | M | 90 |
| ASSEMBLER | M | 5 |
| UTILITIES | M | 2 |
| ARDS graphic package | P | 10 |
| Misc: | | |
| CDC Scope | M | |

C. Hardware

Describe the total computer and peripheral requirements of the project.

1. Main computers used: IBM 360/67
2. Core size required: 220 K bytes
3. Secondary storage devices used: disk, tape
4. Graphics devices used: ARDS storage screen, CALCOMP plotter

D. Accessibility

1. Use of batch processing

   Local: 10 percent of computer budget

   Remote: 0 percent of computer budget

   Turn-around time requirements: 24 hours

PROJECT EVALUATION TEMPLATE

Project Name: Bus Dispatching

2. Use of time sharing

   90 percent of computer budget

   Terminal characteristics

   __x__ Typewriter only

   ______ Card I/O

   ______ Printer output

   __1__ Graphics devices (specify):

   ARDS

   ______ Small computer (specify):

   ____________________

3. Use of real-time systems

   15 Percent of computer budget

   Describe usage: Use of IBM DOS for real-time bus dispatching

E. Characteristics of Worst Cases

Specify the following information for the largest jobs, with respect to each measure, run during the project:

1. Core requirement: 512 K
2. Run time: 30 minutes CPU time
3. Computer charge: $200
4. Printed lines of output: ____________
5. Punched cards output: ____________
6. Punched cards input: ____________
7. Number of I/O devices: ____________

PROJECT EVALUATION TEMPLATE

Project Name: Bus Dispatching

## F.2 STAGE TWO: PROJECT CHARACTERISTICS BY PHASE AND USER TYPE

A. Description of phases and user types for each

(Use additional sheets as necessary)

Phase 1 description: FEASIBILITY STUDY

This consisted of definition of the proposed system to be modelled by a computer program (determination of allowable parameters, system features, etc.) and the programming of such a model. In this phase, the transportation analyst directs the computer programmer.

User type descriptions

1. Transportation analyst
2. Programmer
3.

Phase 2 description: PROTOTYPE DEVELOPMENT

This consisted of building a prototype based upon facts and refined transportation system design based on the successful outcome of phase I. Here the systems programmer defines the main lines of the total computer system which will be used for the prototype. This includes hardware determination, general software system selection, main flow of control between the major components of the computer programs. Based on the general design, much detailed work must be done on the communications to be used by the prototype, as well as careful consideration of real-time demands made by the system and the possibilities offered by the hardware/software combination. The programmer is concerned with writing the programs which must make transportation decisions and which are well defined because of the work done in phase I.

PROJECT EVALUATION TEMPLATE

Project Name: Bus Dispatching

User type descriptions

1. System programmer
2. Teleprocessing/real time programmer
3. Programmer

Phase 3 Description: PROTOTYPE TEST/USE

This phase consists of extensive integration and testing on actual operation. Reliability demands made in this phase far exceed the requirements in phase II. Whereas system construction might have taken place with only a subset of the desired equipment (e.g., no back-up computer), all necessary equipment must be made to function. In this phase operational procedures, personnel training, data gathering requirements are determined in a real, not a simulated, environment.

User type descriptions:

1. Demonstration project personnel

B. Computer requirements by phase and user type. (Use as many sets of four sheets as necessary)

The letter following each parameter indicates whether the parameter is binary, continuous, or a description to be specified:

B - Binary variable, implying a value of yes or no, or a numerical ranking of importance:

1 - not important
2 - somewhat important
3 - very important

C - Continuous variable such as a computer size of 300 bytes.

PROJECT EVALUATION TEMPLATE

Project Name: Bus Dispatching

S - A descriptor to be specified, such as the type of secondary storage specified as tape or disk.

B/S- The first column should contain a binary variable. If this variable is YES, 2, or 3, the second column should specify the requested information.

PROJECT EVALUATION TEMPLATE

PROJECT NAME: BUS DISPATCHING

| | | Hardware Computer Requirements | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Secondary Storage | | | Graphics | | | | | |
| Phase No. | User No. | Core Required (C) | Speed (C) | Type (S) | Size (C) | Speed (C) | Static Pictures (B) | Dynamic Pictures (B) | Graphic Input (B) | Hard Copy (B) | Multiple CPU Processing (B) | Real-Time Facilities (B/S) |
| I | 1 | 256K | 1 μ second | none | | | Yes | | Yes | Yes | No | |
| I | 2 | 256K | " | none | | | No | | No | No | No | |
| II | 1 | 256K | " | random | 30MB | 75 msecs | No | | No | No | Yes | |
| II | 2 | 256K | " | " | " | " | No | | No | No | Yes | |
| II | 3 | 256K | " | " | " | " | No | | No | No | Yes | |
| III | 1 | 256K | " | " | " | " | Yes | | Yes | Yes | Yes | |

PROJECT EVALUATION TEMPLATE

PROJECT NAME: BUS DISPATCHING

| | | Software Computer Requirements -- I | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Operating Systems | | | | | Development Languages | | | | |
| Phase No. | User No. | Time Sharing (B) | Telepro-cessing (B) | Multiple Job Pro-cessing (B) | Utilities (B) | Other (S) | FORTRAN (B) | PL/1 (B) | Assembler (B) | Other (S) | Simulation Languages Used-[1] (B/S) |
| I | 1 | Y | Y | N | Y/N | | N | N | N | | |
| I | 2 | Y | Y | N | N | | Y | Y | N | | |
| II | 1 | Y | Y | Y | N | | Y | Y | Y | | |
| II | 2 | Y | Y | Y | N | | N | N | Y | | |
| II | 3 | Y | Y | Y | N | | Y | Y | N | | |
| III | 1 | N | Y | Y | N | | NA | NA | NA | | |

[1]Examples: GPSS, CSMP, SIMSCRIPT.

PROJECT EVALUATION TEMPLATE

PROJECT NAME: BUS DISPATCHING

| | | Software Computer Requirements -- II | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase No. | User No. | Data Management Support (S) | Real Time Support (S) | Meta-System Support[1] (B/S) | | Package Program Support[2] (B/S) | | Statistical Program Support[3] (B/S) | | Graphics Support (B/S) | |
| I | 1 | | | No | | Yes | BPR | Yes | BIMD | Yes | ARDS |
| | | | | | | | Transet | | SPSS | | |
| I | 2 | | | No | | No | | No | | Yes | ARDS |
| II | 1 | | CP/67 | Yes | CP/67 | No | | No | | No | |
| II | 2 | | CP/67 | Yes | CP/67 | No | | No | | No | |
| II | 3 | | | No | | No | | No | | No | |
| III | 1 | | | No | | No | | No | | Yes | ARDS |

[1]Examples: ICES, PLAN

[2]Examples: BPR, TRANSET

[3]Examples: BIMD, SPSS

PROJECT EVALUATION TEMPLATE

PROJECT NAME: BUS DISPATCHING

| | | Accessibility Computer Requirements | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Batch | | | | | | | | |
| Phase No. | User No. | Local (B) | Remote Terminal (B/S) | | Turn Around Required (C) | Time Sharing Terminal (B/S) | | Real Time Usage (B) | Dedicated Computer (B) | Back Up Computer (B) |
| I | 1 | Y | N | | 24 hours | | ARDS | N | N | N |
| | | | | | | | 2741 | | | |
| I | 2 | Y | N | | 2 hours | | 2741 | N | N | N |
| II | 1 | N | N | | | Y | 2741 | Y | Y | Y |
| II | 2 | N | N | | | Y | 2741 | Y | Y | Y |
| II | 3 | Y/N | Y/N | 2741 | 2 hours | Y | 2741 | N | N | Y |
| III | 1 | N | N | | | N | ARDS | | | |
| | | | | | | | 2741 | Y | Y | Y |

## F.3 STAGE THREE: DESIRED COMPUTER FACILITIES AND MAJOR CONSTRAINTS

The features most desired but not available during the bus dispatching projects were a multiprocessing computer system and an operating system and computer languages designed for real-time use. Multiprocessing is a desirable feature for two reasons. The first and more important is the vastly increased security of operation which should result from its use. A properly designed multiprocessor should be able to continue functioning even when one of the processors has failed. This is of course important since bus dispatching is a real-time public utility. A multiprocessor is desirable because the security outlined above can be combined with improved performance when both processors are functioning.

Given the present state of computing technology, the user, unless provided with great sums of money, rapidly becomes dependent on the operating systems provided with his machine and the languages encompassed by that operating system. An operating system that is designed to handle random-access input/output devices in a multi-tasking manner is mandatory. An operating system that also has features specially designed to permit easy automatic perception and handling of external events in real time, though not absolutely mandatory, is very desirable for bus dispatching. On the same basis that a hardware system can not function in a real-time manner if the operating system does not, the user must have problem-oriented languages that take external, real-time events into consideration.

# APPENDIX G. DEFINITION OF COMPUTER SYSTEM CHARACTERISTICS

## STUDY 1: MAN/MACHINE INTERACTION

This computer system characteristic study is concerned with the user's view of the methods provided for communications between the user and the TSC system. For purposes of discussion, the nature of this communication will be decomposed into two categories, the mode and medium of interaction. "Mode" is concerned with the spatial and temporal gaps which separate the user from the point in space and time where he must submit his input and receive his response. The magnitude of the spatial gap varies from a few feet (a terminal in the office) to several miles (a batch processing service bureau). The importance of a small spatial distance to the I/O device will vary with the frequency of the user's interaction with the computer. The time the user must wait between submitting some input and receiving a response varies from less than a second (a good timesharing system or a dedicated machine) to as long as a week (a long turn-around batch processing service). Here the significance of the size of the gap depends upon both the desired frequency of interaction and the urgency of response.

The "medium" of interaction is concerned with the physical characteristics an interaction device presents to the user. This category is further subdivided into input and output devices. To some users, particularly computer novices, the existance of a convenient physical form for I/O (a graphic display) may be a very important determinant of the perceived effectiveness of the system. To others, the marginal improvement this sort of device yields may not justify the cost. In certain applications, particularly real-time control problems, the existance of particular analog interaction devices may be mandatory.

This study will further analyze interaction mode and medium according to the types of forms expected to be supported by the technology of FY 77. Each of these forms will then be rated according to its importance to various classes of TSC users.

## A. Interaction Mode

Four general classes of interaction mode can be identified in current and anticipated computer use.

1. Batch -- This class is the null alternative for interaction mode since no attempt is made to shorten either the temporal or spatial gap. The actual magnitude of these distances will vary significantly depending on the type of machinery, its load and its location relative to the user. Because the time-space gaps generally preclude very frequent interaction, the type of job normally handled by a batch system will be characterized by a large amount of computation performed without communication with the user.

2. Communication -- This class of interaction shortens the spatial gap without influencing the temporal distance. Typically this mode takes the form of remote job entry - a system characterized by an I/O device located near the user (in his building) and connected via telephone lines to a computer which otherwise behaves as a batch processor.

3. Conversation -- Conversation interaction is a mode that shortens both the temporal and spatial gaps by providing the user with a nearby I/O device (in his office) and the ability to obtain a response from the computer at least every few seconds. Because of these greatly reduced distances, the user can efficiently handle tasks that involve only a small amount of computation between interactions. Systems supporting conversational interaction will permit communication between the user and the computer during a single job. A batch system, on the other hand, will only permit the user to influence his job before he submits it.

4. Real time -- This class of interaction differs from conversation in terms of both gaps. The difference in the temporal characteristics of these modes is not in the

size of the gap, but in the importance of maintaining a specific gap size. In conversation, response should occur within a small amount of time for purposes of convenience, but in real time that response must occur in a specified time or the application will fail. The two modes differ in the requirements for the reliability of temporal gap size, but not necessarily for its absolute magnitude.

Because of the need to monitor some physical activity, the spatial gap in real-time applications is usually reduced to zero. Typical real-time control problems in transportation include air traffic control, bus dispatching, and vehicle monitoring.

To clarify the relationships between the various modes, Figure G-1 indicates typical ranges for the magnitudes of their temporal and spatial gaps. The values shown there should be taken as indicative of performance and not as a precise boundary on the class. Note also that while conversation and real time have the same upper limit on the temporal gap, there is a difference between the behavior of these systems with respect to time.

## B. Input Media

Four categories were defined to describe input media.

1. Keyboard -- Almost all scientific and research input data processed today is at some point input or derived from input at a keyboard device, such as a keypunch machine or terminal device. It is therefore important to make this user interface as responsive and useful as possible. Key-to-tape and key-to-disk systems are very useful in this regard and are extremely desirable when associated with data editing and/or file manipulation software systems.

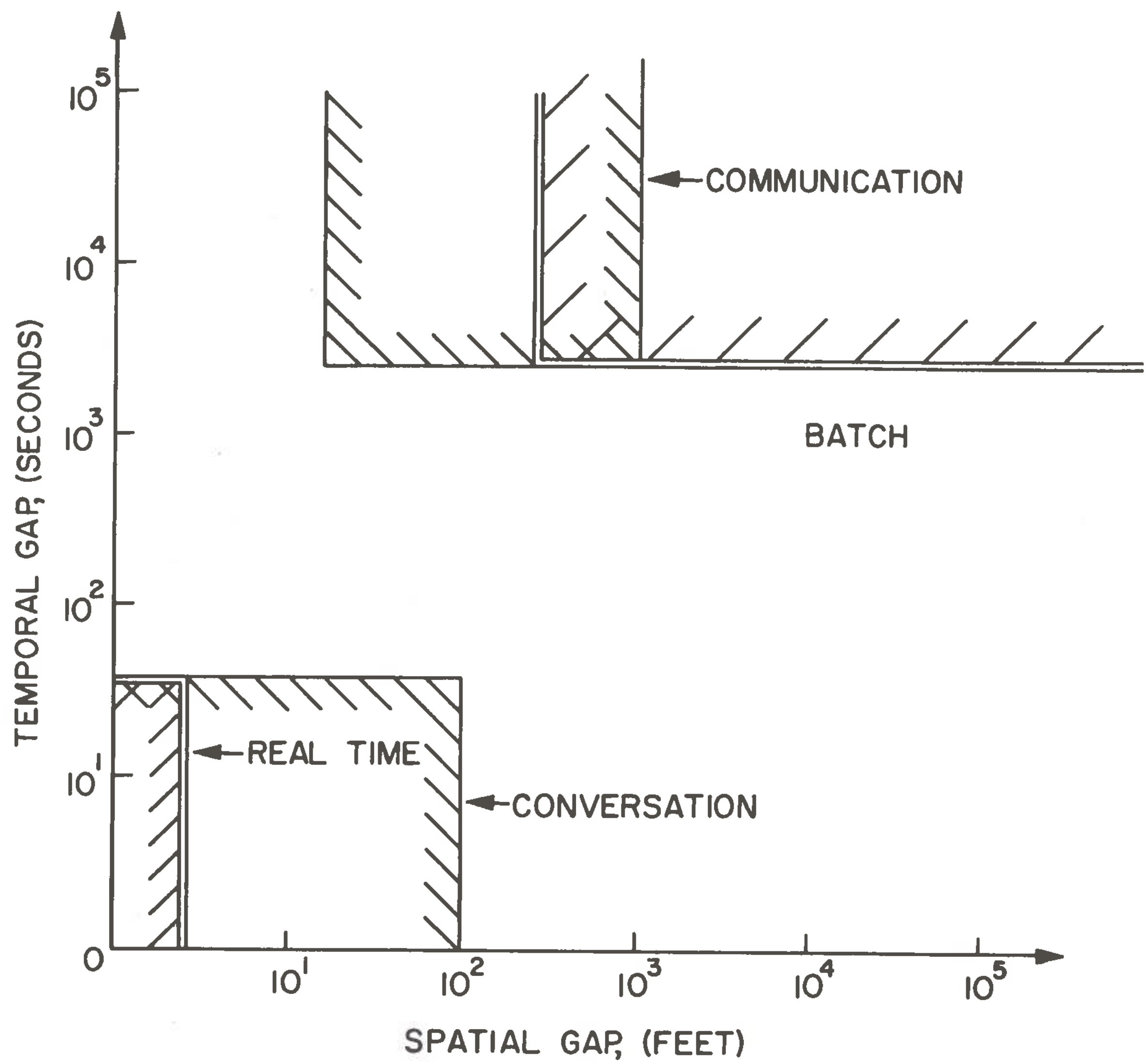


Figure G-1  Typical Performance Range for Mode Classes

2. Analog -- There are two basic types of analog input: "Human" -- Human input can consist of control responses in vehicle simulations, filled in blanks on an optical card reader form or other forms of input readily understandable by the human that the system must interpret. "Mechanical" -- Mechanical input usually consists of meter readings in such applications as process control. Analog input is nearly always used in real-time interaction applications.

3. Graphic -- Graphic input takes a number of forms: "Tablet" -- Curves, lines or in some cases characters or numbers may be input via a writing device to the system. "Digitizer" -- Coordinates of a point are input by placing the mechanism over that point and pressing an input button. "Joy-Stick or Mouse" -- A location on a display is obtained by moving a reference point by means of one of these devices. The reference point coordinates may then be noted.

4. High Volume -- High volume input cannot be handled by some types of input devices (such as teletypes) and may be difficult to accommodate by the computer system itself. Both of these system components should be selected to be compatible with anticipated volume demands.

C. Output Media

Output media categories can be defined in a similar way.

1. Alphanumeric -- Like keyboard input, this is the most common form of output. Again, since this output form is easily understandable to the user, it should be as easily available to as many as possible. Examples include standard alphanumeric printers and keyboard terminals.

2. Analog -- There are two basic types of analog output: "Human" -- The system response is in human understandable form. This may be meter readings, taped vocal phrases or some other action. "Mechanical" -- The system response is a physical alteration of some physical state. This is most common in vehicle simulators and process control applications.

3. Graphic -- Graphic output can have several alternative characteristics: "Static" -- Static graphics are drawings which after being generated must be either added to or completely redrawn -- parts which already exist cannot be updated. Static graphics are in general not associated with real-time interaction. "Dynamic" -- Dynamic graphics are continuously updated. Since changes with time are important in this graphic medium, only the conversational and real-time interaction modes can accommodate it. "Hard Copy" -- It is often desirable to produce a copy of a graphic display on paper or photographic film. Thus, the given display is permanently stored, and the computer can be freed to produce other displays. Note that any graphics produced by batch or communication interaction must be hard copy.

4. High Volume -- Many transportation applications produce large volumes of output, and some output mode available to the user should accommodate it.

STUDY 2: SOFTWARE

This computer system characteristic study deals with basic support programming which is an inherent part of a computer system. The careful design of this aspect of a system will be crucial to its ultimate success. Traditionally, the term software has been used to refer to a set of programs which constitute a basic component of the capabilities of a computer system and which are designed to make the machine more accessible to users. Most such programs are tools which automate the most common tasks of the programmer. Two classes of software which fall into this category will be considered here. These are programming languages and system support. A third class to be discussed is the area of user-oriented language and system support. This latter type of software should be particularly important in the TSC environment.

A. Programmer Languages

Although no specific languages will be discussed here, note will be made of several important language features. Importance here is almost solely related to the programmer, for it is the programmer who will make use of these features (or be hampered by lack of them) and who must master them if the language is to be an asset.

1. Ease of Use -- The language specifications must be non-ambiguous and understandable. Its compiler, assembler, or interpreter must be easily invoked and must produce clear diagnostics.

2. Data Structures -- All languages have some facility for data structuring. The more useful ones include array storage, variable length data, hierarchical structuring, and structure sharing. The more flexible and powerful the data structures, the more work is shifted to the system, freeing the programmer of data storage problems which detract from other work.

3. Extensibility -- A language to which the programmer can add syntactic constructions is known as an extensible language. An example is the macro capability in 360BAL with which repetitive sections need not be repetitively coded. The difference between an extensible capability and subroutines is that the extension is included as part of the language syntax itself, which is difficult, but exists in some compiler structures.

4. Multi-Tasking -- The ability to allocate resources to several tasks which can be executed simultaneously is known as multi-tasking. This feature is most useful in real-time applications where it can relieve the programmer of scheduling tasks which can logically occur in parallel.

5. Recursive Ability -- In its simplest form, a recursive program is one which may call itself as a subroutine. This capability is important for the convenient handling of some types of complex data structures.

6. Applications -- Some languages are designed specifically to perform certain applications, including: Simulation - must be able to handle clocks, special data structures such as queues and user facilities and should permit multi-tasking. Real Time - should be communications-oriented and able to handle various types and volumes of demands, as well as have data and language structures oriented toward real-time processing.

B. System Support

Most programmers communicate their tasks to a computer by means of a programming language, and this constitutes an important component of the system from their point of view. In addition, however, their programs run in some environment which is also a strong determinant of the system's effectiveness. This latter category includes such items as core size, file systems, and callable service subroutines. This system component, which will be referred to as system support, will be analyzed in the next few paragraphs.

1. Virtual Memory -- Under a virtual memory system, the programmer logically has a larger amount of primary memory available to him than that which physically exists. The operating system accomplishes this by retaining on secondary storage sections of the program which are not currently being accessed. When needed, they are brought into primary memory and other sections are sent to secondary storage. This makes the programmer's job easier, because he doesn't have to worry about absolute memory restrictions.

2. Meta System Support -- A meta system is an integrated package of programs which aids the programmer in implementing a user-oriented system. These tools usually aid in the processes of language processing, data structures and inter-program communications. An example of this concept is the Integrated Civil Engineering System (ICES). This is an extremely useful concept which makes it relatively easy to create systems for use by analysts who are novice computer users.

3. File System Support -- A file system is a facility for storing information and accessing it by name. File systems are associative by nature; that is, the user-supplied name is translated by the system into a physical address where the information resides - generally secondary storage. Important features frequently found in file systems include: "Sharing" - accessing of files by multiple users at the same or different times. This flexible attribute allows a much broader use of the file system facility. "Control" - Method of creating, updating, manipulating files; for example, ability to update records or parts of records of a file without reloading entire file. "Protection" - restriction of read and/or write access to certain file structures can be important, especially in a sharing context, but will probably play a minor role in a TSC environment.

4. Utilities -- Utilities are easily operable programs that perform system functions which are often repeated. There are two basic types: "Standard" -- These are usually provided by the system supplier and include file copy and update utilities, sort/merge, report generators, and the like. "Transportation" -- A system serving the TSC community must have a certain number of basic utilities directly applicable to transportation functions. Such utilities would be programs to extract data from census tapes, land use and growth models, 'package' programs to process networks and network-oriented data files, and various types of statistical analysis tools. Inability to easily access such information

frequently hinders research and even design efforts, because obtaining such data becomes a special project and consequently rather expensive.

## C. User Oriented Languages and System Support

Here are included some facilities which are solely user oriented.

### 1. Problem-Oriented Languages

A POL is a language designed to solve a limited and relatively well defined class of problems as opposed to a language such as FORTRAN that is intended to solve any mathematical problem. At the cost of not being able to solve other problems, POL's make it possible for users with little or no computer training to use the computer. For clearly understood technical problems, such as network analysis or structural design, POL's can be very valuable.

2. Time-Sharing -- In this context, only those characteristics users perceive that are distinct from the conversational interaction mode are considered. Principally, this involves the ability to interact with other simultaneous users by treating the computer as an "intelligent" communication link. Note that not all timesharing systems offer this capability. In an environment such as that at TSC where users are likely to be grouped into projects, this feature might be somewhat important. The more common characteristics of a timesharing system (quick response, interaction, etc.) were treated under conversation interaction.

3. Integration -- In an environment such as that found at TSC, where there is a fixed community of users working on different but interrelated problems, the property of integration can be very important to a computer system. Integration refers to the ability to use both programs and data on other projects than for which they were originally intended and to combine them in unanticipated ways with other programs and data. This capability requires both an

operating system which can accommodate controlled sharing of data and programs and the establishment and enforcement of a set of programming conventions. While integration has never been fully achieved in an existing system, this important property should be one of the design goals for a system to serve TSC.

4. Utilities -- Under the heading of user system support, this term refers only to those transportation utilities readily employed by users without programmer aid. Ideally, a TSC system will support many such packages.

## Importance Matrix

The importance matrix in Table 4-4 contains an assessment of the significance of each software category to each user class. Note that the areas of programmer tools (programmer languages and system support) have some sub-categories considered important to non-programming users. This is because:

a. Although the non-programming users are not computer specialists, they may perform some programming functions from time to time; and

b. Certain types of improved programming tools (such as meta-systems) will be reflected rather directly in improved user tools.

## STUDY 3: TECHNICAL DATA STORAGE AND RETRIEVAL

This section deals with facilities for the storage and retrieval of techniaal information within a TSC computer system. This component of the set of user tools is responsible for the maintenance of all permanent data. Specifically, this function involves providing for the definition, creation, interrogation, and updating of data files as well as the generation of reports based on these data.

This discussion will consider four components of technical data storage and retrieval:

A. Modes of user access -- The interface between the user and the system;

B. Associative facilities -- What the system can do for the user;

C. Storage structures -- The prime determinant of operating costs; and

D. Access Control -- The maintenance of privacy and protection for the user's data.

## Modes of User Access

This aspect of the system describes how a user accesses the tools of the facility. This issue can be resolved into two basic parts:

1. Language of Access -- The fundamental difference between systems at this level involves whether the facilities are exercised via an independent language or whether they operate as an extension of the capabilities of a procedural language. The first type, called a self-contained language, offers a limited capability designed for easy use by non-programmers. The second type is called a host language extension and offers a larger class of services to the programming user.

   a. "Self-Contained Data Management Capabilities" -- are basically designed to support the interrogation of data files, Users request that the system display certain subsets of the data which satisfy some criterion the user defines. Usually, complicated data processing is not supported by the self-contained language. The principal advantage of this sort of facility is that users can compose unanticipated queries and have them resolved without requiring the services of a programmer. This facility is most important to the adminstration and design users. They frequently need to access large data files simply to recall certain information but not to perform extensive computation. This mode of access can also be valuable in statistical analysis if the necessary analysis algorithms are included in the system. The principal disadvantages of this approach is that more complicated applications cannot be expressed in the simplified language.

b. "Host Language Extensions" -- are tools provided to programmers to assist them in coding data management applications. The problems to which such facilities are applied will typically involve computations difficult or impossible to express in a simple self-contained language. Host language extensions are simply additions to a standard programming language such as FORTRAN, COBOL, or PL/1. Hence, the programmer may use the facilities of this parent language to express the desired algorithm. This sort of facility is particularly essential if a number of applications require access to a common data base. In all programs which involve a significant amount of permanent data manipulation, a good set of language extensions can reduce programming efforts considerably.

It should be noted that these two kinds of access languages are not dichotomous, in the sense that a system must be one or the other. In fact, a good data management system should be usable in either mode so that both classes of user will be able to access the same data.

2. The Quantum of Access -- This term refers to the quantity of data management activity normally performed to service a single request. Here the two possibilities are batch or unit transactions systems. In a batch operation a number of requests (such as group of insertions or deletions) are transmitted to the system and processed at once. In the other mode, each request is handled invidually. Note that these two modes do not necessarily correspond

to batch processing or timesharing operating systems, although in practice there tends to be a correlation.

a. Batch oriented data management systems have the advantage of efficiently handling bulk operations such as updating telephone directories, personnel files, etc. As such, these systems are very important to standard administrative applications such as payroll production. The complementary problem, however, is that such a system cannot react to real-time user requirements.

b. The unit transactions systems on the other hand are useful for real-time needs, but they cannot take advantage of repetitive nature of bulk requests to achieve the efficiency of batch systems.

Once again, the best systems will combine both of these modes. If bulk requests are indicated by the input language, preprocessing can improve the efficiency of the operation without jeopardizing the system's ability to handle unit requests.

B. Associative Facilities

The associative facilities of a data management system enable the system to store and to retrieve data according to associations which exist in the data base. Normally, these features of a data system are partitioned into two categories: one called the data structure and the other the language for manipulating the data structure. The same level of associative facility can be achieved with many combinations of data structures and languages. It can be misleading to compare two systems by contrasting the two data structures and the two languages separately without considering how these components interact. For this reason, the (data structure, language) pair is considered to be a single parameter which includes the interactive effects.

In order to talk concretely about associative facilities, a very simple data structure is proposed that can form the basis of measuring this parameter. Systems with more complicated data structures can be compared by mapping their facilities into this simple form and adding appropriate language capabilities. This simple structure defines a data base as consisting of a set of files each of which is structured like a table with named columns. The following kinds of associative facilities are of interest:

1. <u>Within Row Associations</u> -- This refers to the ability of the system to identify a particular row of a file by the contents of the row. The possibilities for identifying a row range from simply recognizing a key field to selecting a row based on an arbitrary boolean combination of its elements. The former level of capability may be adequate for certain simple administrative functions, but for other functions, more sophisticated capabilities are required.

2. <u>Between Row Associations</u> -- This level of facility involves the identification of a row based on the contents of that row and other rows. Once again this can involve simply matching key fields of rows in the same file or, at the other extreme, arbitrary boolean combinations involving rows of many files in the data base. Some form of between row associative capability is essential in many applications, particularly those involving networks.

These associative facilities form the heart of a data management system. Every operation of the system - file definition, creation, insertion, deletion, updating and interrogation - involves the exploitation of associative facilities. While it is difficult to define a precise measure for this parameter, it is appropriate to say that a "high" level of associative capability in the data management facility will be a significant requirement of many TSC Users.

## C. Storage Structures

In order for a data management system to be effective it must operate with reasonable efficiency. Storage structure, or the physical representation of data, is the prime determinant of efficiency. The key to considering this aspect of a system is to recognize that the most efficient structure for one application will be inefficient for another. The following are two of the most common kinds of structures and the types of applications for which they are useful.

1. Static Files -- Static files are those which are seldom changed, but rather are normally interrogated as a fixed data base. Such a file should be structured to simplify the process of searching as much as possible. This implies an array-like representation and probably some orderings. Changing the data in a file structured in this way will be an expensive process, but by the nature of a static file we expect this to be a rare occurrence.

2. Dynamic File -- In contrast to the static variety, these files are frequently changed. The array-like ordered structure is thus eliminated on economic grounds. The alternative is some type of list-structured arrangement, which is quite common for this kind of file.

Here again, the best systems will recognize this application dependence of storage structures and provide for a variety of alternatives.

### D. Access Control

The final parameter considered here is access control. This aspect of a data management system can be very important for certain types of data and relatively less vital for others. Probably the user class most concerned with this capability is the administrative user. He is concerned with access control because of the sensitive nature of the data he handles. Thus, he must avoid having users either see the data or change it. Most other users, on the other hand, are only concerned about damage to their data, not unauthorized reading of the data. Their problem can be treated fairly simply by using the "write" control which is a standard feature of today's large computers.

## Matrix Representation of User Requirements

Table 4-5 shows the importance of each of these parameters to the various application classes.