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TRANSPORTATION ANALYSIS AND SIMULATION FACILITIES (TASF) PLANNING AND APPROACH

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16. Abstract

The Transportation Analysis and Simulation Facility (TASF) will be a powerful tool which will greatly enhance the Transportation Systems Center's (TSC) capability to resolve large scale, complex transportation problems. TASF will allow multi-discipline systematic analysis of proposed single and multi-modal transportation problems and provide a multi-faceted overview of the technical, environmental, social-economic and land use consequences of proposed solutions to transportation planners. Utilization of TASF will allow development of systematic multi-disciplinary and qualitative costs and benefits associated with the various approaches to a balanced national transportation system.

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This document has been prepared for the express purpose of soliciting comments concerning the definition and justification of a transportation analysis and simulation facility. The final version of this document will be issued by June 30, 1972. It should be noted that in some places data has been used for purposes of demonstration of approach that is generally correct, but must be verified. Such data is identified as "typical".

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1.0 INTRODUCTION

The Transportation Analysis and Simulation Facility (TASF) will be a powerful tool for improving the industrial efficiency of the United States through increased efficiency of transportation. U.S. transportation costs are on the order of $200 billion per year (20 percent of GNP). The TASF will integrate the technical capabilities of Department of Transportation (DOT) personnel with a computational system to provide a unique facility for furthering the investigation and the improvement of the quality of transportation on the local, regional, state and national level. TASF can be available for use during the years 1976 to 1980, therefore, the use of the TASF will focus on the major transportation problems predicted for that time period. The facility will be constructed on existing government land at the Transportation Systems Center (TSC) and will provide 56,000 sq. ft. of laboratory space for approximately 150 people and the TASF systems.

The Transportation Systems Center is a government-owned installation located in the Kendall Square area of Cambridge, Massachusetts. The site, one and one-half miles west of the center of Boston, Massachusetts, is immediately north of the Massachusetts Institute of Technology, and one and one-half miles from Harvard University.

The TASF provides the Department of Transportation with a capability to provide extensive simulation and analysis of transportation problems in the area of urban, inter-urban, and inter-modal and social economics. The impact on society and the economy of significant transport systems dictates that verification prior to installation of viable alternates be made through use of a TASF. Significant improvements will be made to existing transportation systems through improved operations techniques devised by simulations performed in the TASF. Social-economic impacts of proposed transportation systems will be investigated to ensure the inclusion of latent users and to minimize systems costs.

Estimated Project Cost

Design (Building and Equipment)	$ 700,000
Construction	3,660,000
Equipment	10,960,000
Total Estimated Cost	$ 15,320,000

The Department of Transportation will be the primary user of the TASF and will bear the complete cost of the project. Potential application to local and state planning is foreseen.

In FY72, the analytical and computation support at TSC represented approximately 25 percent of its annual budget. Forecasts show that this percentage will drop to approximately 10 percent of the annual budget in 1976, due to the increased expenditure planned for outside contracts. The TSC budget is projected to be $150 million in five years or less. This result in an annual analytical and computational cost of $15 million. Estimates show that with the implementation of TASF the operating cost will be approximately $9 million. The direct and indirect cost benefit outlined in Section 2.0 far exceeds the reduced operating cost.

Through the use of the interactive man/machine systems of TASF, the total elapsed time required to accomplish a program is reduced by 1/2 to 1/10. This results in significant manpower savings which will pay for TASF in three to five years and more significantly bring the benefits of new programs to the public years ahead of schedule.

Programs such as the Urban Congestion Traffic Flow, in which the goal is a reduction, during rush hour, of 25 to 50 percent, and Improved Rail Scheduling and Control to optimize schedules of Long Haul Freight yield savings up to 5000 times the initial cost of TASF. Facilities such as TASF are currently in existence at General Motors, Rand Corporation, McDonnel Douglas Corp. and other companies. These facilities, as with TASF, are unique to the problems they address. TSC has developed disciplines for modal and multi-modal transportation programs and has computational needs that have not and are not being fulfilled by any federal government or industrial facility. Although interactive computer centers exist within the U.S., it is not feasible to utilize these systems because of the communication system links required.

The transportation programs that TASF will support include air, ground, marine and multi-modal. These programs require support in planning, analysis, design, etc. Transportation planning and analysis impacts future capital outlay and must take into account environmental, social, and economic as well as technological impacts. For instance a Personal Rapid Transit (PRT) system must consider the latent users and land impacts. The design and evaluation of transportation systems must also support the social, economic and environmental needs as determined by program planning and analysis. Exploration of alternate system design through the use of interactive systems in TASF will ensure optimum system design in a minimum of time for such transport systems as the dual mode vehicle, the Tracked Air Cushion Vehicle, Collision Avoidance System, etc.

Simulators improve the efficiency of new systems by allowing confirmation of their design before major capital outlay is made for fabrication. TASF is designed to drive simulators for cockpit display verification, Air Traffic Control (ATC) advanced displays, auto driving simulators for safety studies, etc. When technology does not exist to support a transportation program, basic and/or applied research can often provide the necessary information. TASF will support research through its library search capability, interactive analytical tools and large technical information files. Research in areas of pollution, noise, improved route display, power systems, etc., are typical of programs to be supported by TASF.

TASF will collect and reduce data from test and demonstration programs performed either on-site or at facilities such as Pueblo, Colorado. The communications links also will allow TASF to provide stimulus for test programs where computer control is required. Use of the communication links will enable data to be transmitted to TASF regarding systems performance in actual operational environments such as Airport Ground Traffic Control And Street Network Traffic Flow.

In the remaining sections of this document, the facility and the system within is referred to as the Transportation Analysis and Simulation Facility (TASF). The system within the facility is designated the Transportation Analysis and Simulation System (TASS).

2.0 PROGRAM REQUIREMENTS

2.1 INTRODUCTION

TSC provides a multi-modal transportation research capability for the Department of Transportation and is responsible for examining the transportation programs of the nation from a technological and social-economic viewpoint. The Center carries out programs directed by the Assistant Secretary for Systems Development and Technology and for the operating administrations in the scientific disciplines of planning, research, analysis, testing and demonstrations of candidate systems. Figure 2-1 shows TSC's relationship with DOT's modal administrations with respect to the major transportation program areas. This section will present the history and future trends of TSC transportation programs, the computer support required to complete these programs, and how a Transportation Analysis Simulation System (TASS) will provide the computer support.

2.2 PROGRAM DELINEATION

2.2.1 Future Program Trends

At its inception, TSC inherited personnel with skills strong in the areas of electronic control systems. The FY71 program was planned to take advantage of these

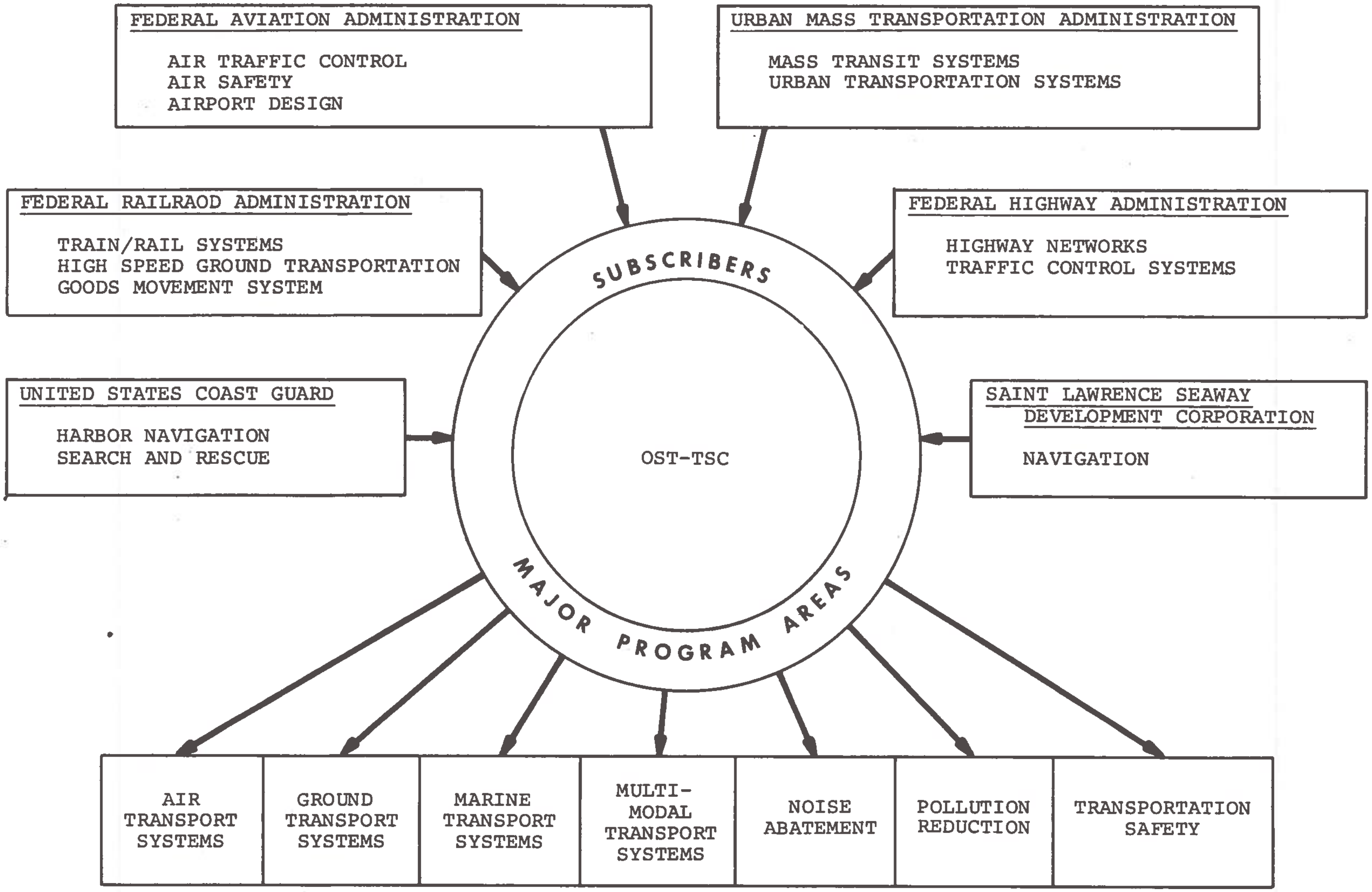
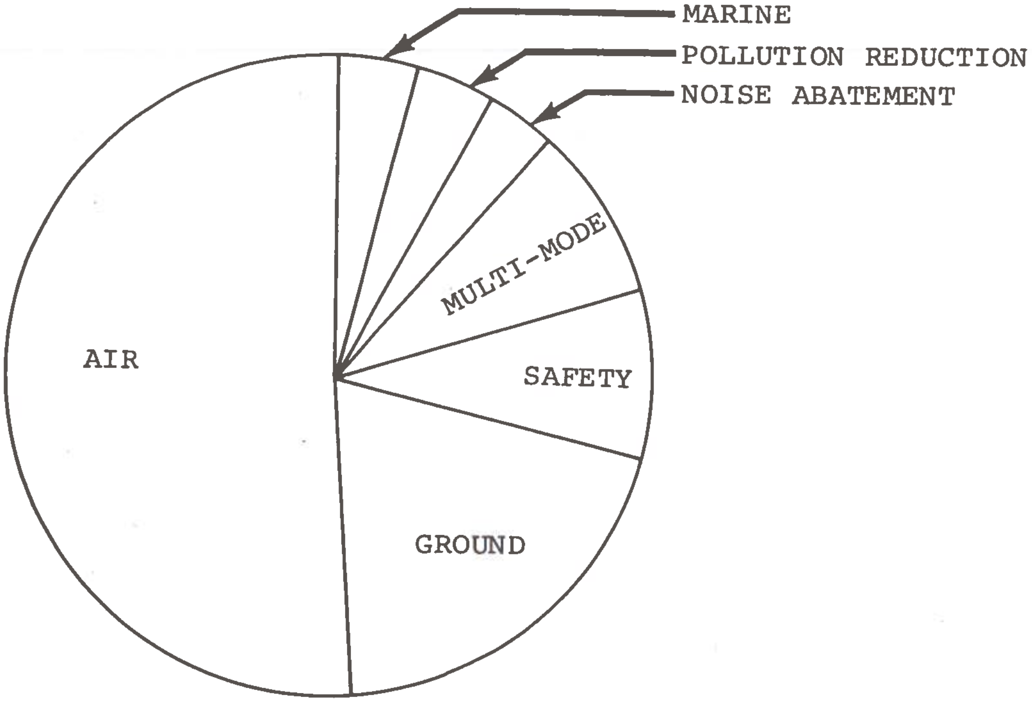


Figure 2-1 TSC Role In National Transportation System

skills, specifically in the areas of sensors, communication and data processing for air transportation systems. Initially TSC was involved in many short-term, low-funded projects which concentrated in research and testing on the component and equipment level. The programs included an operating prototype of a vehicle crash sensor (NHTSA), operating prototype of pilot warning indicator (NASA, FAA), development of a laser fog bank detector (USCG), and a demonstration of an inertial/ILS landing system (NASA, FAA). TSC's role in these efforts has broadened the scope of technical expertise at the Center toward the ground and multi-modal transportation system area. Figure 2-2 illustrates this trend. The FY72 TSC program budget of $32 million includes funding for such diverse programs as the conceptual definition for the Fourth Generation Air Traffic Control System (TST), the management of the Rail Technology Program (UMTA), and the management of the Airport Ground Traffic Systems Program (FAA).

TSC will continue to broaden its technology base by providing program management for a balanced Transportation system. The increasing scope of work is reflected in the *projected* increase of TSC funding based on the assumed TSC growth strategy and 5-year program planning objective [Ref. 1] through 1976 as shown in Figure 2-3. Funding to TSC is anticipated to increase by 560 percent by FY76 from

FY 1971 - $24 MILLION



FY 1973 (PROPOSED) - $55 MILLION

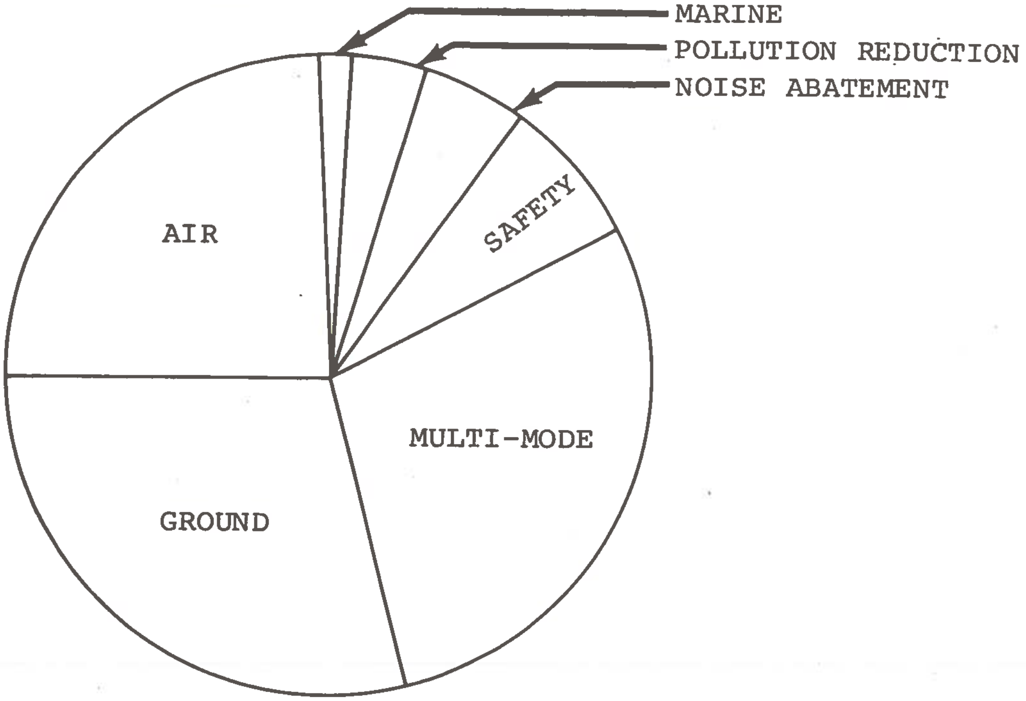


Figure 2-2. TSC Funding Allocations by Major Problem Areas

PROGRAM AREA	FY71 ($1000)	FY72 ($1000)	FY73(1) ($1000)	FY74(2) ($1000)	FY75(2) ($1000)	FY76(2)(3) ($1000)	FY77(2)(3) ($1000)
Safety	$ 3,231	$ 3,975	$ 4,330	$ 9,650	$ 10,650	$ 13,520	$ 15,210
Pollution	645	1,130	1,550	1,140	0	1,350	1,520
Noise	580	975	2,000	2,500	3,000	4,060	4,560
Air	11,966	11,860	14,560	22,900	26,650	33,800	38,030
Ground	3,874	10,632	14,880	25,810	38,580	40,560	45,630
Marine	240	145	350	1,060	1,900	1,350	1,520
Multi-Modal	3,105	3,227	17,855	25,440	34,820	40,560	45,630
TOTAL	$23,641	$31,944	$55,615	$88,500	$115,600	$135,200	$152,100

Notes:

1. Based on TSC FY73 OMB Supplemental Budget Data (October 8, 1971).
2. Based on Reference [1].
3. Program Categories are straight-line extrapolations of averages for FY73, 74, 75.

Figure 2-3. Estimated TSC 5-Year Forecast by Program Areas the FY71 level. A representative list of anticipated transportation program areas and programs which the Center expects to be involved with in FY76 is presented in Figure 2-4 and a detailed discussion of the various TSC program areas and sample future programs [Ref. 1,2,3] is presented in Appendix A.

2.2.2 Automatic Data Processing Trends

At TSC's inception, NASA transferred some of its computational equipment to TSC to perform analysis, simulation and administrative functions. The size of many programs, such as the Airline Passenger and Cargo Demand and Schedule Program, (a relatively small system project), have far exceeded the capability of the existing in-house computation facility and the procurement of out-of-house computer support was necessary in order to successfully complete these programs. Appendix B presents a brief discussion of existing Center ADP equipment and a list of out-of-house facilities which have provided the TSC's additional ADP support.

TSC future programs, Figure 2-4, will be more complex and of greater magnitude and will require more computational support than previous programs. It is projected that $16 million of TSC funding by FY76 will be required for in-house and out-of-house ADP support, as shown Figure 2-5. Future TSC computer support can be provided

	Funding Level[1]
● Safety	
Emergency Medical Services	M
Intersection Improvement	L
● Pollution Reduction	
Surface Propulsion	M
● Noise Abatement	
Airport Noise	L
● Air Transportation	
Advanced Aircraft Technology	M
Fourth Generational Air Traffic Control System	M
Future Data Processing	M
Ground Guidance and Control	M
Microwave Landing System	M
V/STOL	L
● Ground Transportation	
Balance	M
Bi-Centennial Rail and Highway	M
Near Term Improvement in Mass Transit	L
Personal Rapid Transit	L
Rail Efficiency	L
Rail System Support Technology	L
Tracked Levitated Vehicles (TACV/TLV)	M
Tunneling	M
Urban Congestion	L
● Marine Transportation	
Navigation	M
Vessel Traffic Systems	S
● Multi-Modal Transportation	
Northeast Corridor Pilot	M
Satellite	M
Dual Mode	L

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[1] L - Funding anticipated to be greater than $4 million.
M - Funding anticipated to be between $1-4 million.
S - Funding anticipated to be less than $1 million.

Figure 2-4. Projected Major TSC Program - FY76

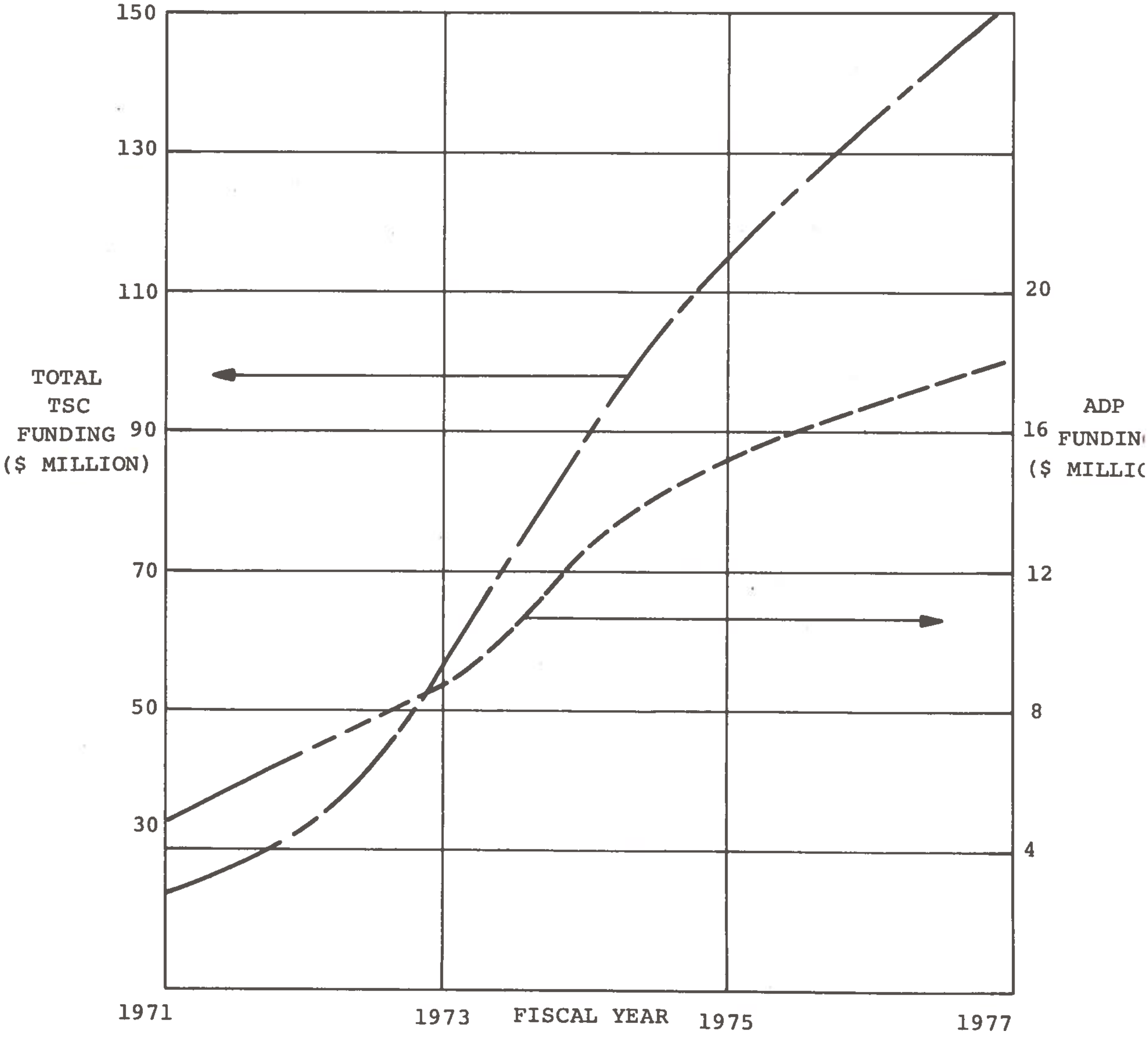

Figure 2-5. Total TSC and ADP Funding Projection

by: (1) continued use of both in-house and out-of-house facilities; (2) out-of-house facilities only; or (3) a new DOT computer facility. The next section will discuss these options.

2.3 SYSTEM UTILITY

2.3.1 Solution of Transportation Problems

Paragraph 2.2 demonstrated the nature and complexity of the transportation problems which the Department will face in this decade. This will be reflected in the increase in complexity and size and concurrent decrease in number of the programs undertaken by the TSC. Thus, TSC will necessarily be concerned with several very large projects. These large projects will comprise many elements whose operations impact each other in complex ways. This often leads to overall systems behavior which is difficult to predict. The analysis of these systems cannot be achieved by the fragmented investigation of the individual components which simplifies or ignores their interaction. The design of a set of optimal elements leads, all too often, to a suboptimal transportation system.

The key to the problem then is to study the transportation system in its entirety, carefully representing each component and its interaction with other elements. While this approach is simple to state, it is quite another matter to achieve it in practice. A great deal remains to be learned in the art of modeling complex transportation alternatives.

The investigation and analysis of a transportation system and its individual components requires the use of a wide variety of computer-based analytical tools during its various stages. In general, these tools are complex and usually are not amenable to use by hand. They include analog models, symbolic or logical models (which may be analytical, deterministic, or stochastic), linear and integer programming models, simulations (either real time or fast time), statistical analysis methods, and data manipulation, presentation, and interpretation systems. As would most people, the analyst may find the mechanics of these aids confusing and frustrating and apply only those with which he is familiar. Efforts which allow him to solve problems at each stage of the investigation using a great deal of computing power and expertise and a variety of approaches (without having to concern himself with the intricacies of the programs) are essential.

The investigation of a complex system comprises several stages (delineated in paragraph 3.1) each of which requires the use of sophisticated research tools such as those mentioned above. The analysis and design stages are examples. The analyst first performs preliminary analysis of available data to increase his understanding of the nature and magnitude of the problem he is facing. He should then use sophisticated predictive models to determine the magnitude and nature of the problem in coming years. These include land use models, demand models, demand shift models, and technology models. The designer will turn to sensitivity analysis and design models during the design phase to develop alternative solutions to the problem; then to large-scale simulations to investigate the effectiveness and impacts of various alternatives. Finally, he will use the interactive capabilities of an evaluation system to interpret the results of each of the alternatives.

Each of these steps requires the application of sophisticated problem solving procedures and a spate of both specialized and generalized data. The nature of transportation systems requires that the investigation be pursued without prolonged interruptions in an environment which provides--through each stage of the program--consistency of approach, consistency of assumptions about the system, and consistency in the data available to describe the system. The analysis must be performed under one system which will permit uninterrupted investigation of the many aspects of a complex system based on common, comprehensive data. If such a system is not available, the analyst has two alternatives: (1) Use only the small, immediately accessible subset of the full range of investigative tools available;

or (2) use a wider variety of analytic tools at different locations with differing data on different computer systems. Faced with the continuous and almost insuperable problem of the integration of these efforts--interpretation of reams of data in a medley of forms and formats, reconciliation of the results of analytical methods based on different assumptions (all of which are probably unknown to the user), and operating on different data (or at least common data which must then be transported from site to site and transformed into varying forms to be used by the different programs)--leaves the analyst with a clear choice: use only what he has most available and attempt to extrapolate and adjust for the many factors and variables whose impacts will never be fully investigated.

An environment which will support the effective analysis and integration of complex transportation systems and provide for the successful completion of programs of the magnitude anticipated by the TSC must provide a powerful analytic and design capability comprising a full spectrum of models, simulations, and design programs coupled with a powerful set of application (special purpose) systems which enable the analyst to interpret and investigate data and results in an interactive environment. It must also provide a large base of common data (such as census data and trends) available to each stage of the analysis and a flexible data base for specialized data required by each individual problem. Finally, it must have a group of highly trained personnel to apply this capability to transportation programs and to aid others in its application.

2.3.2 Advantages of Responsive, Centralized System

The availability of a system with the spectrum of capabilities described provides benefits which can be attributed to two advantages--the development of better alternatives and time savings.

2.3.2.1 Development of Better Alternatives - A centralized, interactive analysis facility has two salient attributes that can lead to better solutions to transportation programs. First, the centralization of analytical software tools and data permit the rapid and effective evaluation of many design approaches to determine the ones which will offer the most reward. The analysts are then able to explore a much wider range of potential solutions. The probability of a better solution is much greater when the analysts use the variety of techniques that a centralized facility provides to explore the "solution space" more thoroughly.

Second, the analyst is more likely to obtain an intuitive "feel" for the problem at each stage of the program when he is able to make modifications almost instantaneously. This increased comprehension of a problem is a phenomenon many have described as "synergy", in which the capability of the computer to calculate very rapidly and that of the analyst to solve problems heuristically (the trial and error approach) are coupled and enhanced by the near-instant response provided through interactive graphics communications.

Given this increased "feel" for the problems faced at each stage of a program, the engineer is able to make even better use of the expanded assortment of techniques provided to him. He is thus able to effectively explore many more plausible solutions and the probability of proposing better solutions is greatly increased. The programs with which TSC is and will be dealing involve important, costly public systems and it is plainly worthwhile to explore alternatives.

2.3.2.2 Time Savings - The time savings associated with the use of TASS result from the common repository of transportation knowledge, its computation capabilities, technical support, and the increased accessibility to the system permitted by the flexible I/O configuration (especially the interactive features). The time saved is in two forms: direct time saved and elapsed time saved.

Direct time saved can be related to the ratio of the time required to perform a specific task entirely with the use of a centralized, interactive analysis system to the time required to perform the same task entirely without its use (although not without the use of a computer). For a specific task, the most important contributor to direct time savings is the interactiveness of the system (i.e. services not available at a non-centralized system can always be obtained elsewhere and transit time would not be a component of direct time). Experience with interactive graphics systems indicate that ratios for direct time savings range from 1/6 to over 1/1000 [Ref. 4,5,6,8,9].

Elapsed time refers to the total time to complete a major program, rather than individual tasks, and thus includes the time for the additional tasks that are associated with a program and that do not benefit (or benefit to a smaller degree) from a system of this type. Elapsed time savings can be expressed as the ratio of the total time to complete a major program with the use of a centralized, interactive system to the total elapsed time required without its use.

Little empirical evidence is available to quantify the elapsed time savings produced by the increased availability of problem solving tools and data due to centralization. For a program requiring the use of a wide range of tools and data, their availability is a significant time factor. Evidence is available which quantifies the expected elapsed time savings due purely to the interactive nature of the system: the ratios of program completion time with the use of the system to that without its use range from 1/2 to 1/10 [Ref. 4,5,6,7,9]. Although this understates the actual elapsed time reduction we expect the system to provide, it can be used as a conservative estimate.

2.3.3 Cost Justification

Currently, TSC maintains a number of small to medium size computers, ranging from the second generation IBM 7094, through the third generation Honeywell DDP-516 to a DEC PDP-10. Although the equipment was excellent for the purpose for which it was originally procured, the demands of transportation problems have stretched its capacity and TSC has been forced to rely on outside computers for additional support. In addition, the newer equipment has a much reduced average lease cost per instruction: an IBM 7094 costs 76 cents per million instructions, while a CDC 7600 costs 2 2/3 cents per million instructions. Figure 2-6 shows this trend. As a result of these factors, TSC will soon be forced to update its in-house computer capability, and will also be forced to continue to rely on additional outside computer systems for support of extraordinary tasks. The projected operating costs of this approach are comparable to the expected operating costs, (including equipment rentals), for TASS. The original $15.3 million investment for TASF, purchases

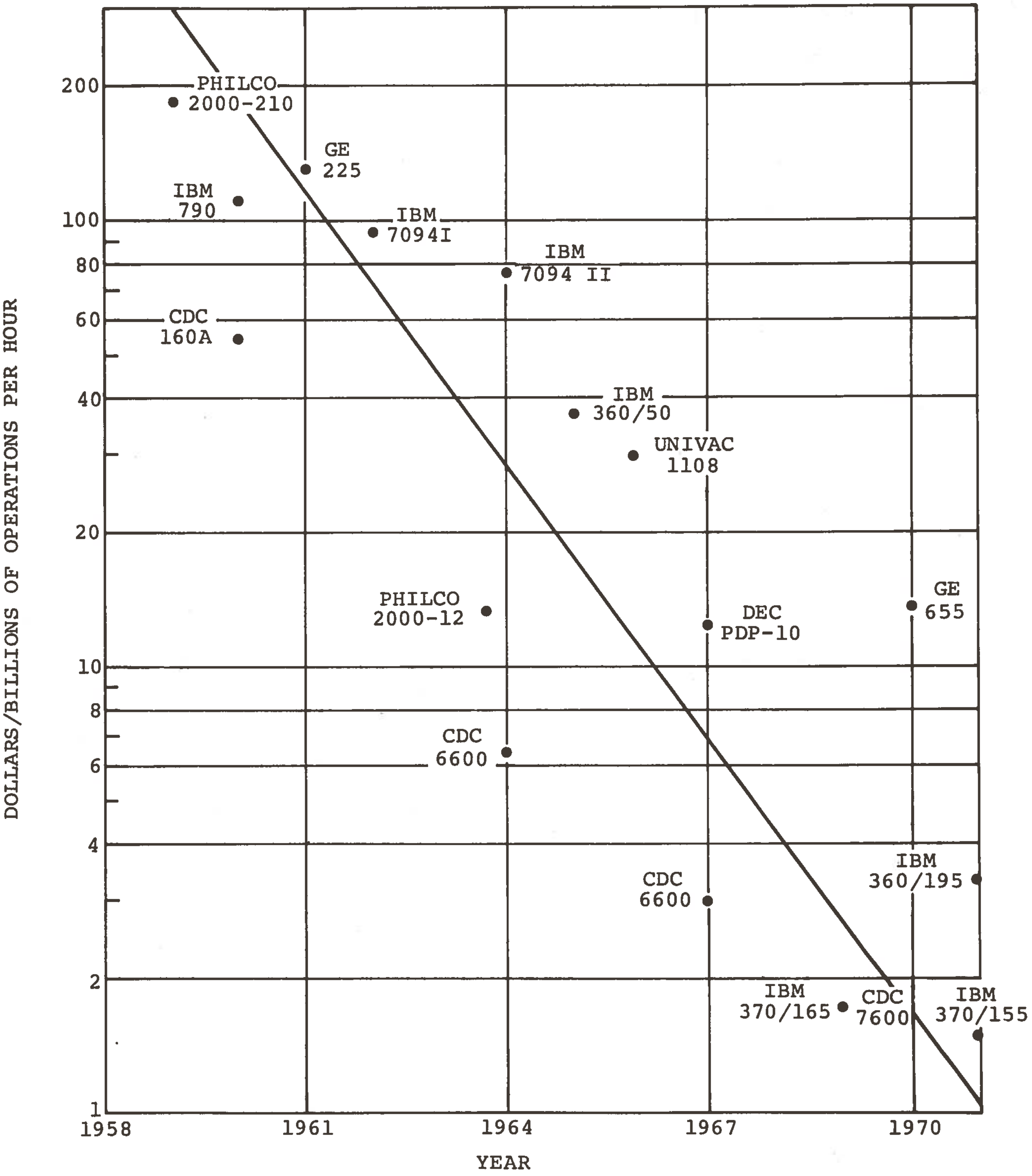

Figure 2-6. Computer Operation Cost (Based on Original Lease Cost)

the system peripherals and software required for a fully integrated, responsive computer system. Thus, the yearly rental charges are expended for a few more powerful central processors which are then placed in a much more accessable, efficient environment.

The value of such a system must ultimately be determined using monetary measures and must be weighed against the required initial investment. In a private firm, such measures are normally contributions to profits; in the case of a public agency, the measure should be net benefit or net cost savings. This type of evaluation, however, must be based on a definition of costs and benefits which is broad enough to include all who will ultimately be affected by a powerful, centralized system for transportation planning. Some cost savings will be directly felt by the public agency which has the system at its disposal. Others, such as reduced operating costs of transportation systems due to the design of better alternatives, will be less directly felt but no less important in the evaluation of such a system.

Thus, the differential cost savings are those offered by a responsive, centralized transportation analysis facility as compared with continuation of the current TSC approach to ADP support comprising a combination of inhouse computer systems and additional support from external services as required. This decision is analogous to the capital equipment replacement problems common to private industry and entails comparison of the present value of the incremental savings to the required initial investment.

2.3.3.1 Indirect Cost Savings - The indirect cost savings are of two types: (1) Those resulting from better solutions; and (2) those resulting from solutions developed and implemented more rapidly.

The continuity of approach through each stage of a program, the increased intuitive feel for the problem, the spectrum of solution techniques, and the time savings provided by a responsive, centralized system produce better alternatives which result in smaller construction costs, lower operating costs and improved safety. The returns to society from this type of savings are difficult to quantify, but they are significant and provide visible improvements that have direct impact on transportation efficiency.

Elapsed time savings reduce the time from project initiation to project completion and thus the benefits of new transportation systems are available to the user at an earlier date. Of the many programs which will be supported by such a system, several deal with problems of such magnitude and have such large potential savings that even small reductions in development and implementation time offer society additional savings which are many times the investment required for TASF.

The first example of such a program is the Urban Congestion Traffic Flow Program. Its goal is a system comprising area wide combinations of computer traffic light control systems and ramp metering which would decrease overall travel time during rush hour by 25 percent in 50 urban areas. The complexity and integration required make the analysis, development, testing, and implementation of these systems a staggering job. The City of Cambridge alone, which is only a portion of the Boston metropolitan area, has approximately one thousand intersections with associated link and demand data for every combination. These requirements simply overpower present capabilities.

Traffic and control strategies exist for accomplishing only limited versions of such systems. Development of improved strategies and full scale systems for real-time traffic control will result in time savings to individuals, improve safety, reduce accidents, and produce enormous productivity pay-offs. This may reduce auto liability insurance by as much as 30 percent, with a direct cost reduction of: (\$100/year/car)(10^8 cars)(.30 reduction)(67 percent of cars in urban areas) = \$2.0 billion/year. Presently, intraurban goods movement cost is about \$30 billion per year. Increases of average velocity for trucks of 10 percent could be transposed into 5 percent efficiency savings: (.05)($30 billion) = $1.5 billion/ year. Without consideration of time savings to citizens and reduction in inconvenience and discomfort due to accidents, the total savings amounts to $3.5 billion per year. Improvement netting as little as one tenth this amount in efficiency of urban traffic congestion systems would result in annual savings of $350 million.

A second example is the development of an Improved Rail Scheduling and Control System to optimize scheduling of long haul freight. Development of this system requires the simulation of both the present national rail freight system and a variety of proposed scheduling systems. This involves the representation of 33,000 miles of track, interfaces between seventy railroads, 1000 depots, 100 classification yards, 20,000 links connecting depots and yards, 3,000,000 freight cars and 100,000 locomotives.

The arrival time of goods shipped by cross country freight car can only be predicted to occur in a particular week with 90 percent accuracy. The major reason for low railroad service reliability is that: freight trains are not scheduled on a national basis; there are frictional effects at the interfaces between the nation's 70 railroads; and present freight train assembly operational philosophy requires that trains of about seventy cars be assembled (in order to keep labor costs to a minimum) which is extremely difficult and time consuming without the aid of national scheduling. Implementation of a national freight train scheduling and control system and coordination with smooth intermodal rail/truck facilities for pick-up and delivery could result in savings of $14 billion per year due to reduction of national manufacturing inventories, reduced highway construction, and reduction in loss and damage costs [Ref. 1]. Improvement netting one tenth this amount would result in annual savings of $1.4 billion.

Successful completion of these two programs would result in annual savings totaling $17.5 billion. Thus, for each one year reduction in the development time of these two programs provided by TASS, society receives an additional benefit of $17.5 billion. Assuming that both of these programs would normally require ten years to complete, the most conservative estimate of an elapsed program time ratio, which is 1/2, indicates a completion date five years ahead of schedule and an additional benefit to society of $87.5 billion--over 5000 times the initial investment required for TASF.

Assuming that these programs return only 10 percent of the savings anticipated, each one year reduction in their development times produces additional savings of $1.75 billion. An elapsed time ratio of 1/2 would shorten development time by five years and provide an additional savings of $8.75 billion or over 500 times the initial investment required for TASF. Alternatively, if these programs are only 10 percent successful, a decrease of only 0.1 percent in the normal development time of ten years would equal the initial TASF investment.

These are only two examples of programs already planned whose benefits are of such magnitude that reductions in their development times offer rewards many times the cost of TASF. Many more will doubtless appear as we move toward the 1980's and the medley of transportation problems the nation will face in that decade, and as the capabilities of a centralized transportation analysis system are assimilated by those who must solve those problems.

2.3.3.2 Direct Cost Savings - The direct cost savings expected from a centralized, interactive system are a result of the time savings mentioned in paragraph 2.3.2.2. The increased productivity results from the decrease in project elapsed time, which enables the same staff to complete more projects--and the decrease in direct time which enables each engineer to work on additional tasks each day.

The direct time ratio applies only to those tasks which involve direct use of the system, while the elapsed time ratio includes the time to complete *all* tasks in a given stage of a program--both those expedited by such a system and those that are not. As the work a man performs each day comprises both types of tasks, the decrease in project elapsed time is the best estimate of the increased manpower productivity this system would provide. The elapsed time ratios presented in paragraph 2.3.2.2 are based on time savings afforded by the interactiveness of the system and do not include those afforded by the increased availability of software systems and data. Although this understates the expected increases in productivity, it provides a lower bound for them.

The ratio of expected elapsed time to complete a given stage of a project with the use of this type system to that without its use ranged from 1/2 to 1/10, [Ref. 4, 5,6,7,9], or an increase in appropriate manpower productivity of 2/1 to 10/1. A conservative estimate of the expected return due to time savings can be made using a ratio of 3/1 (rather than using the median ratio of 6/1)--remembering also that this does not consider the added return due to direct time savings, which were estimated to be in the range of 6/1 to 1000/1.

By 1976, TSC will employ better than 1000 personnel and it is estimated that at any given time the work of thirty to 70 people (3 to 7 percent of the total) will require active involvement with computer systems while the work of another 25 to 30 percent of the personnel will require partial use. Assuming 1976 manpower costs of $48,000 per year for staff at the appropriate level, the annual savings expected from an elapsed time ratio of 3/1 for 50 personnel actively using the system is $4.8 million--$48,000 times 50 people times 3, minus $48,000 times 50 people times 1 (the cost which would be incurred in any event).

In comparing these savings against the initial cost of such a facility, one cannot simply add $4.8 million for each year; the money saved during future years must be discounted at some rate which reflects the time value of money and the opportunity costs borne by the economy for deferring other possible investments of public funds. Most sources (including OMB) recommend that the "public discount rate" should be 10 percent. Figure 2-7 depicts the cumulative, discounted savings for ten years and indicates that with 5 percent of the personnel actively involved with the system, these savings alone will offset the initial investment at the end of the fourth year. Figure 2-8 shows the number of years required for the discounted savings to offset this investment for varying ratios of time savings. As this ratio approaches the mean, the initial investment is offset during the second year.

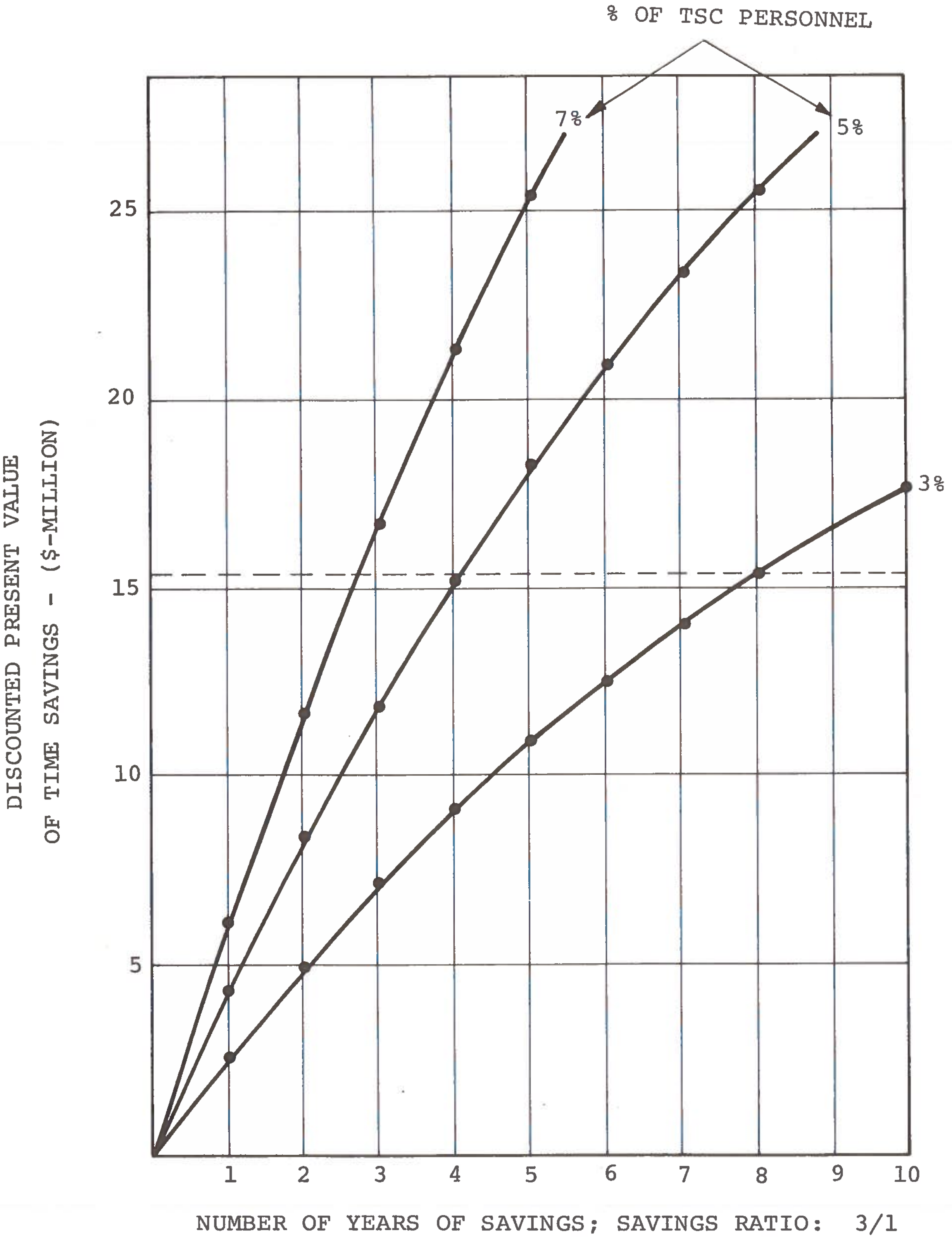

Figure 2-7. Discounted Present Value of Time Saving (Cumulative

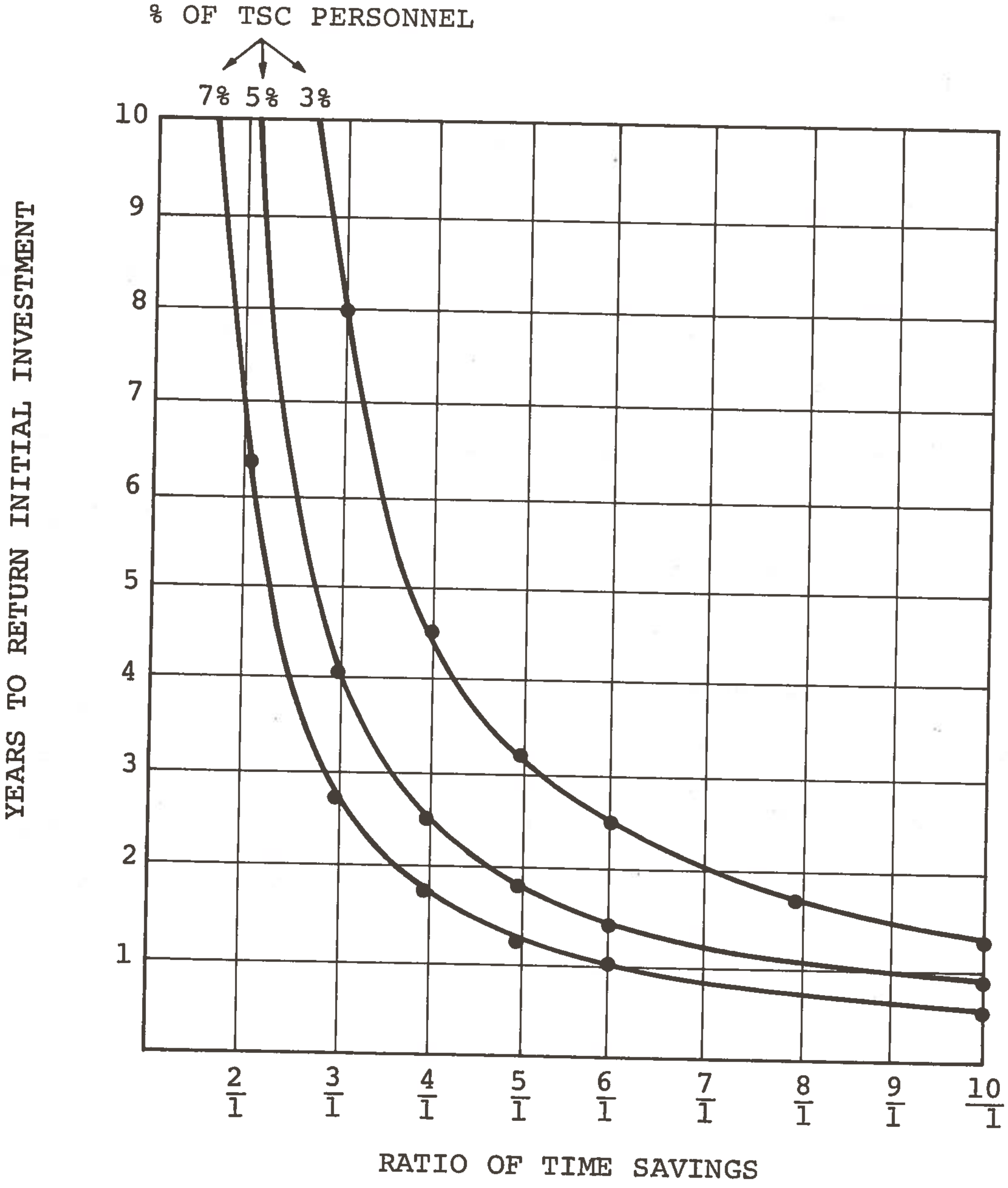

Figure 2-8. Years to Return Initial Inventment Vs. Time Savings Ratio

2.3.3.3 Cost Summary - Based purely on direct cost savings to the Department, the initial investment of $15.3 million for the development of a transportation analysis and simulation facility would be quickly recovered. With conservative estimates of 3/1 time savings and 5 percent of TSC personnel actively involved with the system, the investment is recovered by the end of the fourth year, and the net present value of the savings for the first ten years is approximately twice the initial investment.

These figures, however, are based on a definition of costs and benefits much too narrow to include all who will ultimately benefit. The unquantifiable benefits--such as improved safety, smaller operating costs, and decreased travel time--due to the design of better alternatives are less directly felt by DOT but are perhaps even more important. Finally, the reduction in the time required to complete programs which have large potential savings for society offers substantial rewards--many times the cost of the system--to the public and is thus the most cogent argument for its implementation.

2.4 REFERENCES

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3.0 FUNCTIONAL REQUIREMENTS

The DOT programs projected for the 1976 to 1980 time period require computational capability for the TSC engineers and scientists that exceed present or projected capabilities. The functional requirements that are placed on the Transportation Analysis Simulation System (TASS) by the TSC disciplines supporting these programs will be integrated into a system proposed for the Transportation Analysis and Simulation Facility (TASF). A typical transportation program has been divided into disciplines for the purpose of quantifying systems requirements. These disciplines apply to the total of DOT; however, for initial TASS definition purposes, TSC programs and disciplines were used. As more detailed work is performed toward the operational date of TASF, the functional requirements will be refined. The functional requirements determine the capacity, performance, and user requirements for the TASS, and, because of the wide range of support requirements, they establish priorities for the major design goals.

3.1 DISCIPLINE SUPPORT REQUIREMENTS

The disciplines chosen to represent a typical transportation program are listed below:

- Planning
- Research
- Analysis
- Design

- Evaluation
- Fabrication
- Demonstration
- Program Control.

Figure 3-1 illustrates the TSC disciplines used to support the 1976-1980 transportation programs. The figure shows only major discipline support, as almost all of the programs require some of each discipline. Program control is not shown because it is present in all programs.

Figure 3-1 also indicates that for the programs projected for the 1976-1980 time period, a clear emphasis is on *research*, *analysis*, and *design*. Figure 3-2 identifies the major functional requirements for TASS by discipline. The figure depicts the relative importance of having a capability for each functional discipline. The following paragraphs describe the disciplines and the requirements they place on TASS.

3.1.1 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

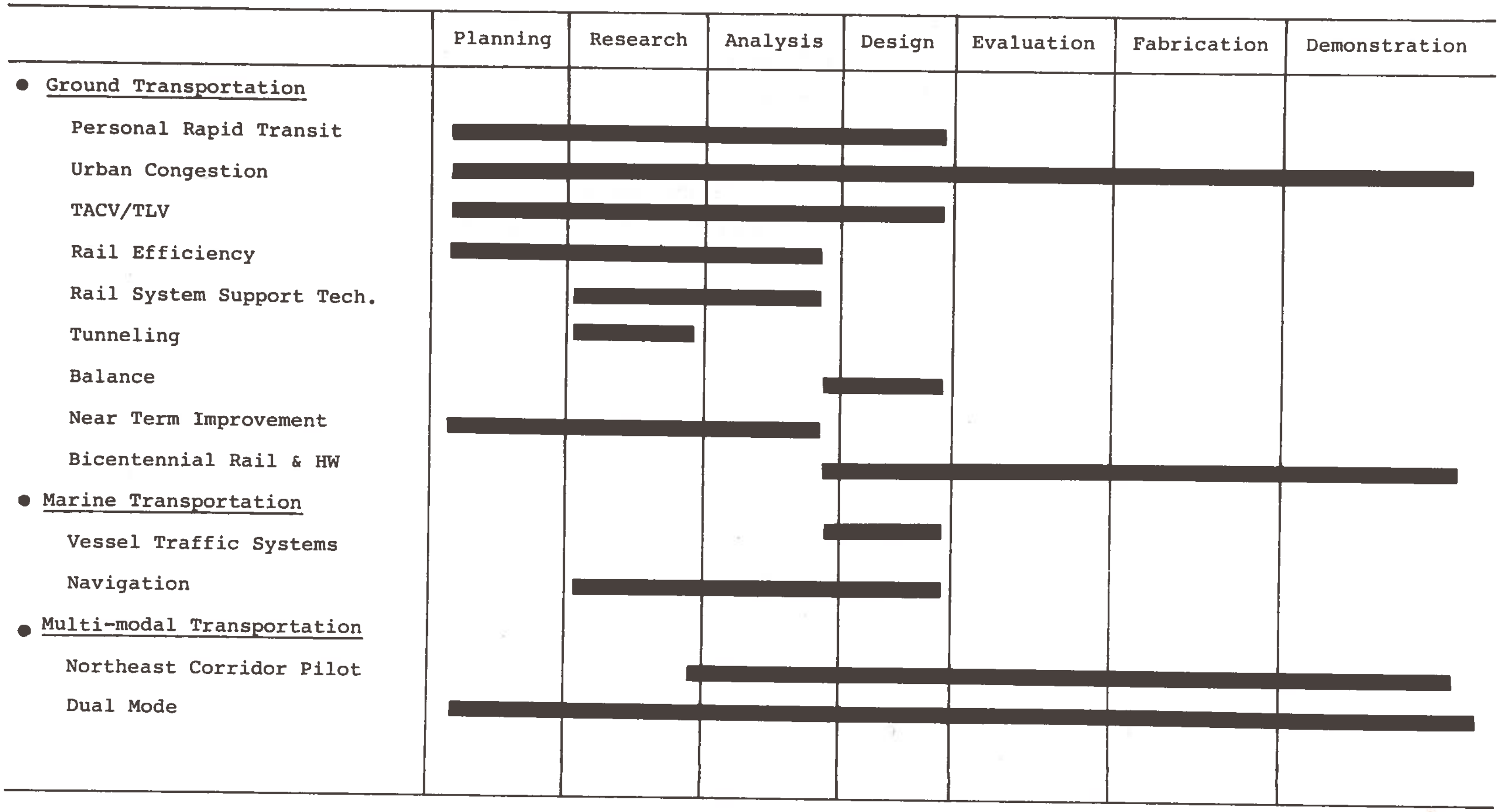


Figure 3-1. TSC Program Responsibilities - "Typical" (Sheet 1 of 2)

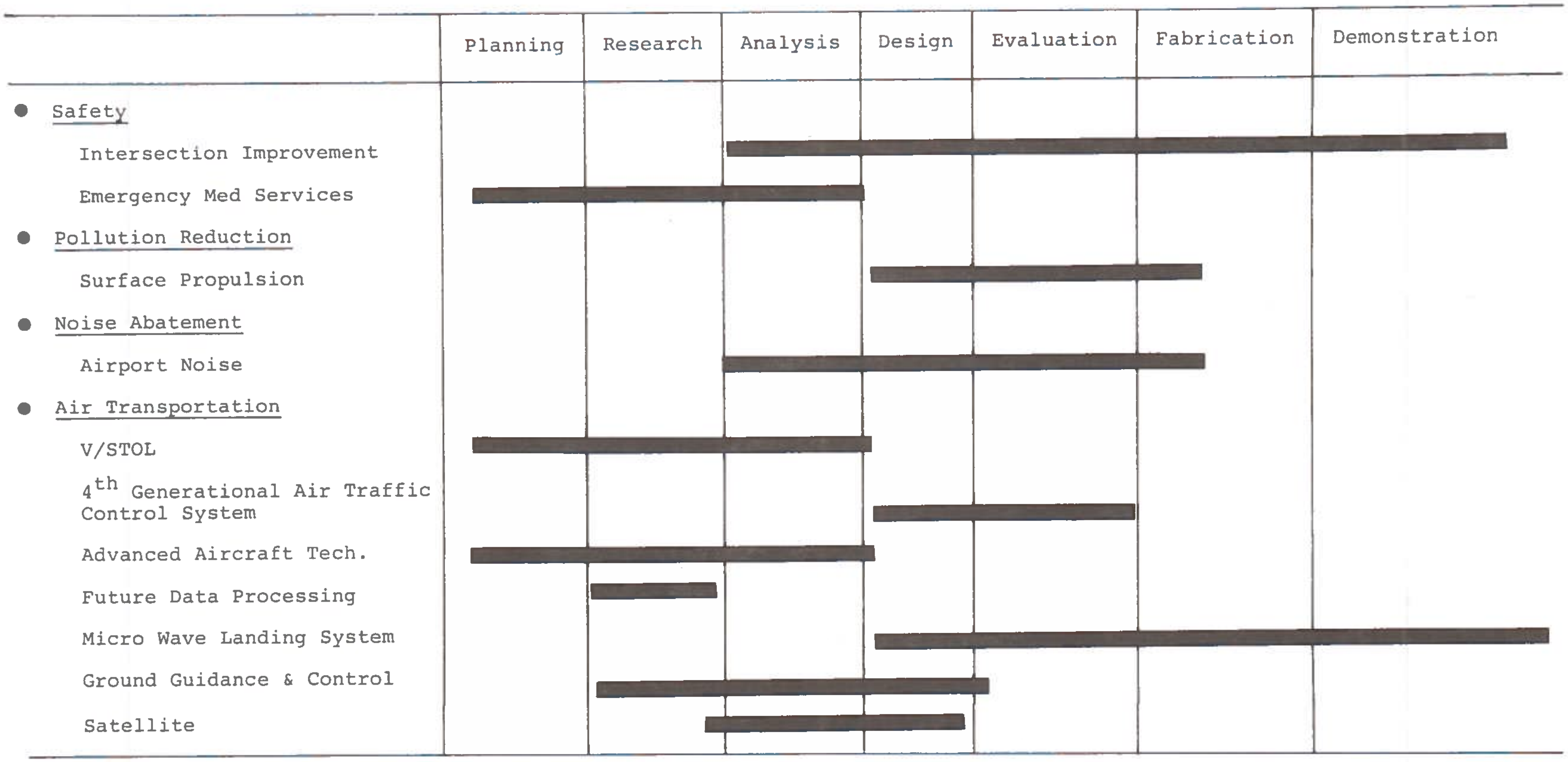


Figure 3-1. TSC Program Responsibilities - "Typical" (Sheet 2 of 2)

Capability Program Discipline	Mass Storage	Batch	Data Reduction	Interactive Computation	Graphics (Interactive)	Graphics Input	Graphics Output	Large Scale Display	Modeling	Simulation	Library Service	Management Information System	Documentation Processing	Remote Data Access	Remote Access	Central Access
Planning	M	M	H	H	D	H	H	D	H	-	H	M	M	-	M	D
Research	M	H	M	M	H	D	H	-	D	H	M	-	H	D	M	D
Analysis	M	M	M	M	M	M	M	H	M	H	M	-	H	D	M	D
Design	M	H	H	M	M	M	M	D	H	D	H	-	H	-	M	D
Evaluation	H	H	M	M	H	H	H	D	M	H	D	-	H	D	H	D
Fabrication	-	D	D	-	-	-	D	-	-	-	D	H	H	-	D	-
Demonstration	H	D	M	H	-	-	D	H	D	H	D	D	H	D	D	D
Program Control	M	M	H	H	-	-	H	-	-	-	M	M	M	-	M	D

M - Mandatory
H - Highly Desirable
D - Desirable
- - Not Required

Figure 3-2. "Typical" Functional Requirements for TASS environment forces special attention to be placed on intragroup 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. All of these efforts, as shown, involve extensive study of large amounts of data where planners are searching for trends and information on which to base transportation plans. The planners are involved with very large populations and networks that require mass storage of information which must be made available to the planners in this immediate work area. Since the amount of data and the types of computer programs used by the planner are generally very large, batch processing under remote control is the prime computing mode. However, interactive displays will be required for evaluating and inputting large volumes of data generated and used by the batch models. As planning tools, gaming models have been successfully used by transportation planners at all government levels. The models are generally smaller than the planning models and are operated in an environment where pseudo-governmental officials interact with each other, with the result of their actions being predicted through models. This type of planning requires that common displays be provided to all participants. Large scale displays are very desirable for this activity.

3.1.2 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. Most of the research work is accomplished with small computer programs or calculators. This type of operation makes mandatory, interactive computational systems (such as is used by the RAND Corporation), where small programs can be run interactively and the researcher can have access to a wide variety of data. Since the researcher is making more frequent, smaller calculations, his access to immediate computational capability is required.

3.1.3 Analysis

Systems analysis is understanding, evaluating, conceiving, and/or improving of 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.

Because of the broad scope of work performed during system analysis, group displays are required that will enable a maximum of five analysts to work a specific problem. A single room is required that will allow analysis work to be performed and coordinated. The room may also be used for such activities as training and gaming exercises. Because of the multiple viewers, large scale displays are required.

The computation required for the analysis of transportation concepts involves the use of large amounts of data and a variety of analytical techniques. Although not always complicated, these calculations can be laborious and time-consuming and can burden the analyst with routine work. TASS will present the full modeling and computational capabilities of the facility to the analyst at his desk. Network data, vehicle characteristics, and other data can be accessed from the TASS data banks and used in the analyst's own program or in a program available in the TASS library. Because of the necessity to analyze the characteristics of the physical and operational transportation system, such as dual mode vehicles, schedules and networks, graphic input/output from TASS is required.

3.1.4 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, components and schedules 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.

TASS will permit rapid and effective evaluations of many design approaches to determine the ones that will provide optimum cost-benefit.

The design of transportation systems, new vehicles, and system components will be accomplished through computer-aided design techniques. Such techniques have already been used in the aircraft and automotive design fields with proven effectiveness. TASS will enable these techniques to be applied to prototype tire design, airport design, and other transportation fields. TASS will provide interactive graphics, on-line computation and hardcopy for the designer.

3.1.5 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 a general knowledge of the engineering field which produced the sample for testing. As the transportation systems being tested become larger and larger in scope, the computer tasks of experiment control and data reduction will become larger. In many proposed new systems, the investment is so great that detailed concept evaluation must be performed prior to hardware development.

The evaluation of a final design is a critical step that will be accomplished through models and simulation.

For the evaluation of transportation systems in which the human operator or controller plays a key role, it is necessary to faithfully model the system and its environment.

Man-in-the-loop simulations are valid tools for evaluation of systems concepts and equipments as well as being a powerful tutorial tool, as demonstrated by the success of NASA, military, and civilian efforts involving real-time simulation. Candidate real-time simulations for TASS are operations of an urban transportation system monitor and control room, advanced air traffic control room operations, and evaluation of driver response to alterations in vehicle design, changes in the display of information, increase in environmental stress, changes in control procedures or regulations, and other similar variations in operating conditions. Fast-time simulations or modeling is also a powerful tool of the engineer performing concept or system evaluation. This requires interactive systems in order to be most productive with remote access and a capability to reduce evaluation data to meaningful information.

3.1.6 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 percent of the cost of a major transportation system, improved technique of manufacturing can result in significant cost savings.

The requirement of fabrication of TASS is through management information systems, documentation processing, etc. For large systems spare parts and inventories would be maintained.

3.1.7 Demonstration

Demonstrations leading to operating systems is 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.

TASS will provide the capability to gather data for performance evaluation of large demonstration systems. Closely associated with the demonstration task is the test engineering functions. Test engineering is the branch of engineering associated with the evaluation of systems, subsystems and components. The test engineer formulates the testing plan, the parameters to be measured and the test acceptance criteria as well as manages the performance of the actual test. Test engineering requires that a number of skills be used which are independent of the item to be tested as well as a general knowledge of the engineering field which produced the sample for testing. As the transportation systems being tested become larger and larger in scope, the computer tasks of experiment control and data reduction will become larger. Test beds can be expected to be located both on-site and off-site. TASS will provide control and data reduction for closed-loop and/or open-loop tests. Two-way data communications (high and low speed) between the test bed and TASS with logging of the data being exchanged over the data lines, and output of test results in graphical and tabular form is required.

3.1.8 Program Control

The TSC program manager, the functional organization manager and his management and administrative support personnel all need to prepare reports and maintain files to manage their programs. The most effective means of performing these functions when dealing with complex projects or large amounts of information is automation. The relatively new concepts such as decision modeling combined with the established concepts such as critical-path project planning show a broad use of computation in efficient and effective management.

TASS will contain the software and storage capabilities required to provide up-to-date, accurate information regarding projects, personnel, funding and other related items to upper-level TSC management. Terminals remotely located from TASS will provide information upon request from the user. Safeguards will be incorporated to prevent unauthorized access of this information. In order to keep the data bank current, TASS will incorporate source data automation (direct conversion of information from original document to machine code) to make this function and other data input functions an efficient, cost-effective process.

3.2 CAPACITY AND PERFORMANCE

The capacity and performance requirement of TASS is based on the functional requirements of the disciplines supporting the projected programs of the FY76-80 time period. TASS must provide for each discipline a mix of interactive processing, batch processing and simulation capability that will allow program objectives to be accomplished in a minimum of time and cost. Continued refinement of the capacity and performance requirement will be made as more information concerning the magnitude of transportation programs, available data bases, math models, simulation programs, and functional requirements are obtained. Although more difficult to determine, the time period over which the transportation program is to be accomplished plays a vital role in determining performance. To insure consistancy and successful operation of TASS at the initiation of operations, limited interactive systems that are available today will be monitored to insure validity of requirements. Also during the development phase, applicable software packages that are identified as candidates for use at TASS will be exercised, under actual operating conditions, to the maximum extent possible.

3.2.1 Access Requirements

Critical to the design of TASS is the population of users it must support. Estimates are made from the total population that will use the TASS and of the population that at any instance will demand access for computational needs. Also distinction must be made of the type of support that the user requires i.e. batch, interactive, or simulation. Estimates of total CPU hours have been made in Figure 3-3. These estimates are based on using a machine equivalent to a CDC 6600. The total time is then divided into the types of usage needed by each discipline. The results of this tabulation shows a minimum of two shift operations where one shift is devoted to batch processing and the other shift is for interactive support and simulation.

Although not shown in Figure 3-3, TASS will support personnel in other organizations within DOT (such as OST) and other departments of the government. The system will be made available to universities, state and local government and possibly to private industry (GFE). Exploitation of users outside DOT has not been fully analysed, however a significant work load on TASS is estimated because of the availability of large transportation data bases and the fast turn-around time offered. Figure 3-4 shows 43 percent of TSC as the user population. The projected instantaneous population actively using the interactive capability is 5 to 6 percent of TSC personnel. This results in a Center requirement for 32 to 40 terminals. Because of the necessity to run large batch models on frequent occasions, remote batch capability will be provided for planning and analysis disciplines. The remote interactive terminals must be able to

PROGRAM DISCIPLINE	PROJECTED AVERAGE NO. OF TASKS/YEAR (1)	AVERAGE COMPUTER HOUR PER TASK (HR.)^{I} (2)	TOTAL COMPUTER HOURS^{II} (HR.) (1)x(2) (3)	% COMPUTER UTILIZATION (%) (3)/4130 (4)	COMPUTER USAGE BY MODE						COMPUTER PERFORMANCE				COMPUTER CAPACITY (10^{-6} BYTES)		
					INTERACTIVE MODE		BATCH MODE		SIMULATION MODE		INTERACTIVE MODE (SEC.)		BATCH (HR.)				
					% USAGE (%) (5)	TOTAL CPU HOURS (HR.) (3)x(5) (6)	% USAGE (%) (7)	TOTAL HOURS (HR.) (3)x(7) (8)	% USAGE (%) (9)	TOTAL HOURS (HR.) (3)x(9) (10)	MIN.	MAX	MIN.	NORMAL	INTERACTIVE	BATCH	SIMULATION
PLANNING	10	85	850	20	20	170	80	680	-	-	1	7	.5	4	10	20	
RESEARCH	15	30	450	11	80	360	20	90	-	-	1	7	.5	4	5	10	
ANALYSIS	17	65	1100	27	40	440	60	660	-	-	1	7	.5	4	10	20	
DESIGN	16	30	480	12	70	336	30	144	-	-	1	7	.5	4	5	5	
EVALUATION	10	70	700	17	20	140	20	140	60	420	1	7	.5	4	5	10	10
FABRICATION	7	5	30	1	80	24	20	6	-	-	1	7	.5	4	2	1	
DEMONSTRATION	7	16	120	3	40	48	60	72	-	-	1	7	.5	4	1	2	
PROGRAM CONTROL	25	16	400	9	30	120	70	280	-	-	1	7	.5	24	.2	.2	
TOTALS			4130	100%		1638		2072		420							

NOTES: I. ONE HOUR OF INTERACTIVE CPU TIME EQUALS 10 HOURS OF CONSOLE TIME.
II. COMPUTER HOURS ESTIMATED ON A MACHINE EQUAL TO CDC 6600.

Figure 3-3. "Typical" Capacity and Performance Requirements

Program Discipline	Percent of TSC per Discipline (%) (1)	Estimated Percent of Discipline using TASS (%) (2)	Percent of Total TSC Manpower (%) (1)x(2)
Program Planning	15.0	50	7.5
Research	7.5	25	≃2.0
Systems Analysis	5.0	80	4.0
Design	17.0	60	10.0
Evaluation	9.0	80	7.0
Fabrication	7.5	25	≃2.0
Demonstration	5.0	10	.5
Program Control	34.0	30	10.0
Total	100.0		43.0

Figure 3-4. "Typical" TASF Utilization at TSC

exercise control over batch processing and access the data generated. Figures 3-3 and 3-4 summarize the capacity and performance requirements on TASS and TSC's utilization.

3.2.2 Capacity

Transportation problems effect almost the total population of the country. When attempting to solve a particular problem such as establishing the need for a Personal Rapid Transit (PRT) or dual mode system, very large volumes of data are required in the planning and analysis. For instance, in dealing with freight rate problems, one encounters three trillion different fares, or in planning an urban network for a city of 100,000 population, the number of intersections and vehicles needed to be controlled are in the thousands. Also, in modeling air traffic control, several thousand airplanes must be accounted for concurrently. The transportation engineer will not attempt to solve his problem on a machine that takes many hours of computing time to reach convergence. Also, if a facility is consumed for long periods of time, it eliminates other tasks from being accomplished, thereby not only reducing the efficiency of the single problem, but impeding the total support effort. Therefore TASS must support multiple users with computational support sized to meet the task efficiently. Extrapolations from past and present computational needs to capacity and performance requirements of the future are speculative, especially if tremendous growth is anticipated. The projections included here are of the most conservative nature in order to show the absolute need, even under minimum conditions. For instance, the present day terminal performance requirements on an interactive system are sufficiently high, (1 second to 7 second response maximum), that any cost for improving on this would be wasted because the user would not normally recognize the improvement.

The program sizes for TASS are extrapolations from present models that are in use today. For instance, the intercity transportation models used in the optimization of airline routes requires a computer with the capacity of 2,250,000 bytes, and this is approximately one fifth the total computer program. Optimization programs that require 20 million bytes are a realistic estimate for planning and analysis needs. One of the major problems facing people in the transportation business is the limited size of computers to handle large tasks. For instance, detailed studies of the air traffic control radar beacon system have placed computer needs as high as 12,000 hours of CDC 6600 time. TASS will provide computational capacity commensurate with the planned programs.

4.0 TASF DESCRIPTION

4.1 INTRODUCTION

The purpose of this section is to present a conceptual description of TASF to give some insight as to what TASF may consist of in terms of TASS hardware and software, and building facilities. This description is the basis for implementation cost estimates presented in Section 5.0.

4.2 TASS

4.2.1 System Requirements

The TASS conceptual design is based on the functional requirements defined in Section 3.0. Following are major system capabilities resulting from the functional requirements:

a. The solution of large, complex transportation problems requires a large scale scientific computational capability.

b. The information management systems and large sized data bases require a substantial mass storage capability.

c. The interface with real-time simulators requires powerful computational capability, high data transfer rates and special interface equipment.

d. The use of numerous interactive graphics terminals requires a graphics system to efficiently handle the work load.

e. The simultaneous access to the system by many and varied users requires special executive software to handle the input/output (I/O) and to effectively monitor and control utilization of system hardware and software.

f. The capability to interactively build transportation models requires a problem-oriented software system capable of building problem languages.

g. The capability to run programs developed on other computational systems requires a large repertoire of compilers, assemblers, and interpreters.

4.2.2 Design Objectives

Along with being designed to meet the functional requirements, TASS will be designed to meet the following cost effective objectives:

a. *Use of Proven Systems* - TASS will be designed to utilize proven hardware and software. Design will allow utilization of the latest state of the art technologies without impacting system implementation.

b. *Growth Potential* - TASS will be designed to allow for future expansion capabilities. System design will be modular to allow add-on or replacement of new system features.

c. *Flexibility* - TASS will be designed to allow varied equipment and software configuration capabilities in order that efficient combinations of components can be utilized.

d. *Reliability* - TASS will be designed to facilitate maintenance procedures for hardware and software. Modular design of hardware and software will be utilized to enhance quick interchangeability of faulty equipment parts and correction of coding errors.

4.2.3 System Description

A conceptual TASS is illustrated in Figure 4-1. The major components of the system are described below.

4.2.3.1 Computation Subsystem - The Computation Subsystem will be utilized to perform the problem solving and simulation computations required of TASS. It will be capable of multiprogramming with a time-share monitor being one of the allowable programs in the computer. The Computation Subsystem will be spared from high I/O, low computation tasks by the other TASS subsystems.

The Computation Subsystem will consist of a large-scale scientific computer. However, the subsystem will be designed to accomodate additional computers.

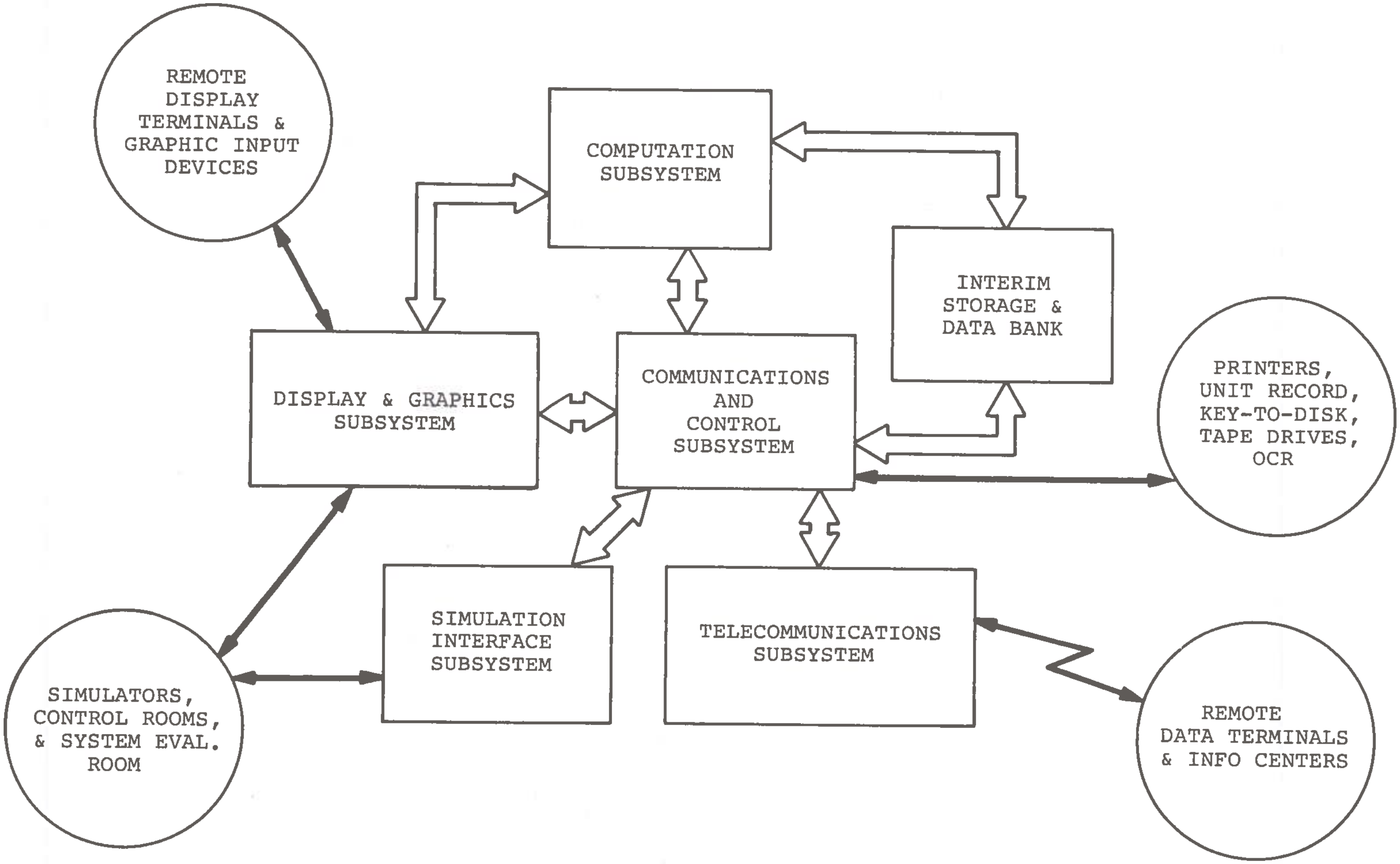


Figure 4-1. Conceptual TASS Configuration

4.2.3.2 Communication and Control Subsystem - The Communications and Control Subsystem will essentially control all activities of TASS. It will monitor TASS system activities and allocate TASS resources to meet the dynamic demands upon the system.

The subsystem will control I/O processing to decrease the I/O demands on the Computation Subsystem. It will control data movement to and from the peripheral devices. It will also perform a data management function.

The subsystem will require a computer with exceptionally fast I/O and data management capability.

4.2.3.3 Display and Graphics Subsystem - The Display and Graphics Subsystem will perform the input, computation and output processing tasks necessary to interface with and drive the various display devices of TASS. This subsystem will be integrated with the Communications and Control Subsystem and together they will relieve the Computation Subsystem of a substantial amount of display input/output tasks.

The Display and Graphics Subsystem will handle all interactive display inputs, perform data manipulation and formatting computations, and distribute display data to the appropriate display devices.

A display processor will be utilized to provide graphics with high dynamic capability and rapid interactive response. There will be a minimum of data communication with the Computation Subsystem; only changes to data content will be exchanged.

The Display and Graphics Subsystem will support a number of remotely located display stations located throughout the Center. It will provide alphanumeric and graphic information to the remote user at a station with any of several interactive devices. These remote display stations will be modular in construction and will allow many configurations of keyboards, light pen, tablet, trackball, or other devices. The subsystem will accept video or digitized inputs of maps, drawings, and pictures to allow mixing of these inputs with computer-generated graphic information. Hardcopy of the computer-generated graphics and the mix of computer graphics and video or digitized input will be provided by the system at the user's command. The subsystem will also be capable of driving large-screen displays.

4.2.3.4 Telecommunications Subsystem - The Telecommunications Subsystem will perform the switching functions to provide two-way data communications of different data rates to remote terminals, internal and external to TSC. It will support data exchange between TASS and demonstration and testing facilities. Dedicated lines will be provided to facilities requiring heavy utilization of TASS. Users in DOT headquarters, universities, government agencies or temporary field locations will have the capability to dial-up access to TASS. In addition, automatic dial-up equipment will permit dissemination of batch program overload to other computation facilities, data exchange with other facilities and access to special computation facilities such as the ARPA network.

Software support for data communications will be located in the Communication and Control Subsystem, but the necessary message buffering will be provided by the Telecommunications Subsystem.

4.2.3.5 Simulation Interface Subsystem - The Simulation Interface Subsystem will perform the data conversion and buffering tasks required to integrate transportation simulators with TASS. The present design approach is that the real-time simulators will contain the analog computation equipment for computations more readily solved by analog computers and TASS will provide the digital computers for computations more readily solved by digital computers.

The subsystem will have a data distribution capability to accomodate various simulator configurations. It will transfer discrete, digital and analog data associated with push-button controls, control sticks, digital readouts, status lights, and meters which might be used in a mock-up of an advanced air traffic control center, an automobile simulator, or an urban transportation monitor and control center. The subsystem will perform the Analog/Digital and Digital/Analog conversions required on the data being transferred. The converters will be patchable to the different devices.

4.2.3.6 Interim Storage and Data Bank - The Interim Storage and Data Bank will provide the high speed mass storage for the storage of programs and data which must be readily accessible by the TASS subsystems. The high data transfer rate will enhance the multi-programming capability of TASS.

The interim storage capability will be used in conjunction with the Communication and Control Subsystem to efficiently transfer large amounts of data.

4.2.3.7 Peripheral Devices - TASS will contain the usual computer peripheral devices such as card readers, card punches, printers, magnetic tapes and disks.

TASS will also accomodate peripheral devices such as:

a. Remote display terminals and graphic input devices.
b. Optical character recognition equipment.
c. Key-to-tape or disk equipment.
d. Cartridge tapes.
e. Microfilm recorders.
f. Plotters.
g. Digitizers.

4.2.3.8 Software - The system software will be designed to facilitate the solution of transportation problems by the users of the system. It will also perform the task of integrating the various TASS subsystems into an efficient working tool. The following software capability will be provided:

a. Executive programs to control the execution of other programs and system utilization. A multi-programming executive will allow a number of user programs to simultaneously compete for physical resources, thereby making the most effective utilization of the system. A time-share executive will allow several users located at terminals throughout TSC and outside the Center to have on-line access to TASS.

b. A problem language system to allow the building and utilization of transportation problem languages. Users will be able to directly formulate programs to solve transportation problems. The system will allow a consistent approach to solving the numerous transportation problems.

c. Interactive Graphics Programs to provide a dynamic man/machine interface.

d. Compilers, assemblers, interpreters to allow utilization of programs developed at other facilities.

e. Utility programs to handle the routine tasks applicable to many problem programs.

4.3 BUILDING

The initial estimate is that the building will enclose a gross area of approximately 56,000 square feet in order to house the equipment and to provide a working space for approximately 150 people. The building will have three floors and will be of permanent fire-resistant construction. It will contain the necessary utility lines and equipment such as fans, pumps, electrical transformers and convertor regulators as needed to provide the special environmental requirements of the system equipment and working area.

An intercommunications subsystem will be provided to allow continuous voice communications throughout the critical operational areas of the facility. It will support both maintenance and operations activities.

5.0 IMPLEMENTATION AND OPERATIONS

5.1 INTRODUCTION

This section describes a plan for TASF implementation and operations support. Cost estimates are provided to give an indication of the scope of the effort. However, more precise cost figures will become available after more detailed study phases are concluded.

5.2 IMPLEMENTATION PLAN

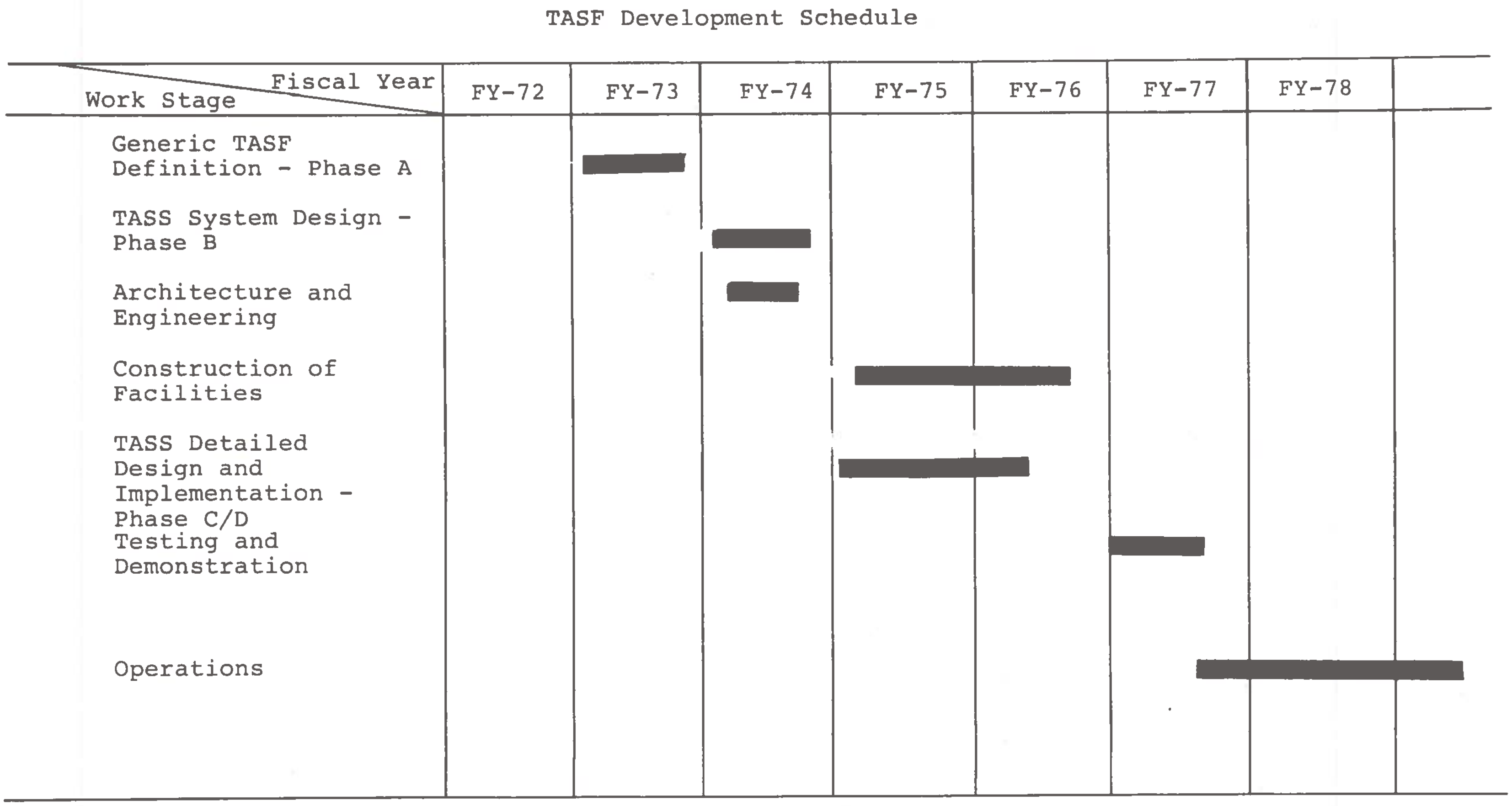
The following work stages are proposed for the development of TASF:

a. Definition of TASF requirements and generic TASF definition--Phase A study
b. TASS design and layout--Phase B study
c. Architecture and Engineering (A&E) design
d. Construction of Facilities (COF)
e. Detailed design and implementation--Phase C/D
f. Operation--Phase E

The schedules of these stages are shown in Figure 5-1.

5.2.1 Phase A

A Phase A study contract will be let. User requirements will be gathered, integrated and analyzed. The most promising design approaches which can satisfy the requirements will be defined and a cost/benefit study made using specific criteria. A design approach will be selected



TASF Development Schedule

Figure 5-1. TASF Development Schedule

and further study will be performed to arrive at a generic system definition. An implementation plan will be generated which will include cost estimates. The output of the Phase A study will include requirements for building design, a detailed definition of the Phase B task, recommended facilities operations support and management procedures, and operations cost estimates.

5.2.2 Phase B

A contract will be let for a system design concurrently with the architecture and engineering (A&E) effort. Close coordination will be required with the A&E effort to ensure that requirements for floor space, power, and air conditioning are considered.

The system design will be based upon the design approach of the Phase A study. The system design will consist of a hardware/software design of each subsystem and each major system component. Equipment sizing, performance, and data interface specifications will be generated. The software will be designed and specifications for each software package will be generated.

The specifications will be for subsystem design. The output of Phase B will serve as input to the Phase C/D effort.

5.2.3 Architecture and Engineering (A&E) and Construction of Facilities (COF)

The building will be designed to meet the requirements specified in the generic design (Phase A) and the Phase B systems design. It must ensure that the building conforms to city building codes and is proper in appearance. The A&E will specify all heating and cooling systems, etc. The output of this will lead to the construction of facilities contracts.

5.2.4 Phase C/D

A contract will be let to perform the detailed design and implementation of TASS. Phase C/D will be closely coordinated with building and construction since installation of equipment cannot begin until joint occupancy (JOD). The system specifications from the Phase B effort will be used to perform the detailed design of the system components. Lease/purchase decisions and equipment procurement will be made in the initial period of Phase C. Detailed hardware and software specifications will be generated. Hardware and software will be implemented and tested during Phase D. Training courses will be provided on TASS utilization. Operating documentation will also be provided. The system will be considered operational upon the completion of rigid system testing and demonstration.

A phase-in procedure will be utilized to ensure a smooth transition into TASS. During the phase C/D time period software techniques to be used in TASS will be demonstrated on interim facilities. Where possible, new hardware techniques will also be demonstrated prior to implementation.

5.2.5 Phase E

Operations support contracts will be let at approximately six months prior to the system becoming operational. The contractors will assist in the checkout and testing of the system and will support demonstration programs. Upon completion of Phase D, the support contractors will operate and maintain all of the equipment and will implement minor modifications on direction from the government. Strict configuration control of both software and hardware will be maintained by the government.

5.3 COST ESTIMATES

Cost estimates for each phase are based on an appraisal of the magnitude of TASF and on the experience gained in similar activities. The estimates will be revised as work progresses through Phases A and B. Final costs will depend on the results of the competitive bidding process for system implementation.

5.3.1 Cost of Major Work Stages

The estimated cost of each stage is tabulated below. Phase A and Phase E are not included because Phase A will be project funded and Phase E will be funded from overhead.

Phase		Cost in $1000
Phase B (System Design)		$ 500
Architecture & Engineering (A&E)		200
Construction of Facilities (COF)		3,660
Phase C/D (Detailed Design and Implementation)		10,960
	Total	$15,320

5.3.2 Phase C/D Cost

Phase C/D costs are divided into two basic categories; hardware and software. Hardware costs include design, fabrication, procurement, integration, and checkout. Software costs include design, coding, integration, and testing. Cost estimates of major hardware and software are itemized below.

a. *Hardware* - The Computation Subsystem processor, Communications and Control Subsystem processor, and Display and Graphics processor are not considered as procurement because they will be leased and are considered as operations costs. However, other costs associated with the equipment are considered.

Equipment	Cost in $1000
Computation Subsystem	$ 100
Communications and Control Subsystem	450
Display and Graphics Subsystem	2,000
Simulation Interface Subsystem	1,500
Telecommunications Subsystem	750
Interface Buffers	1,500
Intercommunications Equipment	310
Total	$6,610

b. *Software*

Type of Software	Cost in $1000
Executive Programs	$2,000
Problem Oriented Language System	1,000
Interactive Graphics Programs	700
Compilers, Assemblers, Interpreters	350
Utility Programs	300
Total	$4,350

5.4 MANAGEMENT AND OPERATIONS

5.4.1 Approach

Appropriate TSC organizational elements will provide the support required to manage and operate TASF. Management procedures will be established to provide centralization of Automatic Data Processing and simulation activities, to maintain control of hardware and software modifications and to efficiently utilize software, hardware and manpower resources.

Building maintenance and operations will be included within the Center's normal facilities activities.

Support to the Transportation Analysis and Simulation System (TASS) will be provided by an efficient combination of Civil Service and contractor personnel. Civil Service personnel will primarily be involved in definition and planning of system modifications and in control of resources. Contractor personnel will be used for the implementation, checkout and operations of TASF.

5.4.2 TASS Supporting Disciplines

TASS support will consist of system design, and maintenance and operations.

5.4.2.1 System Design -

a. *Function* - This discipline will be responsible for maintaining the design integrity of TASS, including system hardware, operating system software, and special software support packages. Expertise will be provided in the following technical areas:

- systems integration
- computer systems
- display systems
- communications
- simulators
- systems interfaces

- system languages
- problem-oriented languages, and
- software operating system design.

Requirements of the varied technical and administrative users will be integrated and strict configuration control maintained. It will ensure that adequate design specifications are generated and that new equipment and software undergo rigid testing procedures.

This discipline will also provide the technical support to investigate and analyze system problems encountered by users of TASS.

b. *Manning* - This function will be performed with a small group of Civil Service specialists and a larger group of contractor specialists. The Civil Service personnel will be responsible for generating general design specifications and for directing the efforts of the supporting contractor.

Detailed hardware and software design specifications and implementation of system modifications will be performed by contractor support elements because the required technological skills to perform these functions are readily available from industry. Also, a number of non-professional services will be required which can best be accomodated by contractor support.

5.4.2.2 Maintenance and Operation (M&O) -

a. *Function* - This discipline will be responsible for the maintenance and operations of TASF. It will ensure that TASS resources are efficiently utilized. The following M&O tasks will be performed:

- scheduling of equipment
- configuration control of computers and simulation equipment
- system preparation for users
- computer operation
- batch processing
- key punch operation
- tape library and disc maintenance
- documentation storage
- periodic equipment checkout, and
- maintenance of spare parts.

b. *Manning* - This function will be performed with a small group of Civil Service specialists and a larger group of contractors.

5.5 OPERATIONS COST

Annual operations costs will be categorized as follows:

a. Manning

- Civil Service manpower
- Contractor manpower

b. Facilities

- Building
- System equipment

5.5.1 Manning

The estimated manpower breakdown of an operational system is as follows:

Discipline	Civil Service	Contractor	Total
System Design	13	25	38
Maintenance and Operations	10	50	60
Total	23	75	98

The estimated annual manning costs are as follows and are expressed in $ million.

Discipline	Civil Service	Contractor	Total
System Design	$0.63	$1.25	$1.88
Maintenance and Operations	$0.48	$1.80	$2.28
Total	$1.11	$3.05	$4.16

5.5.2 Facilities

The estimated annual facilities costs are as follows:

Facility Items	Cost in $ million
TASS Lease Item	
Computation Subsystem Processor	$1.80
Communications and Control Processor	$0.90
Display and Graphics Processor	$0.70
Bulk Storage	$0.60
Subtotal	$ 4.00
TASS Maintenance and Modification	
System Hardware Modification	$0.40
Spare Parts	$0.30
Subtotal	$ 0.70
Building M&O	$ 0.15
Total	$ 4.85

5.5.3 Operating Cost Summary

The total annual operating cost in $ million is:

Manning	$4.16
Facilities	$4.85
Total	$9.01

The total annual operating costs represent 6 percent of an anticipated TSC budget of $152 million per year.

APPENDIX A

FUTURE PROGRAMS

I. AIR TRANSPORT SYSTEMS

In the field of air transportation systems, TSC will continue to participate with NASA in developing V/STOL aviation systems concepts. Significant effort will be undertaken at TSC toward the goal of improving the flow and control of air traffic as the airways and airports become increasingly congested and passengers experience increasing delays in air travel. The primary program to which TSC is committed involves the preliminary design of an advanced Air Traffic Control System. Successful control of the nation's airways requires design and development efforts in data processing, improved communication and navigation systems, and improved pilot aids and landing systems for air operations under adverse weather conditions. The design of these systems necessitates extensive simulation and analysis of air transportation scheduling and flow control.

- *Program example:* V/STOL SHORT HAUL TRANSPORTATION The long term goal of the program is the multi-fold improvement in short haul aviation system productivity, reduction in aviation short haul door-to-door travel time by 25 percent, and the world leadership in aviation technology and sales. With the development of the V/STOL aircraft and airports, a significant reduction in air traffic and airport congestion will occur. This congestion now wastes air traveler's time and adds significantly to noise and air pollution (22 million pounds of pollutants were produced in 1969 because of air traffic delays). Estimated total loss to commercial airlines and air travelers due to congestion amounted to $620 million in 1969; projected annual losses by 1980 are $610 million for air carriers, $370 million for air passengers and $17 billion for landside delays for a total of $2.68 billion. Major TSC tasks in the program include: (1) identify sites within an urban area which would be suitable for use as V/STOL airports; (2) develop ideal airport designs; (3) determine private and social costs and benefits of V/STOL operation and estimate air fare structure; (4) develop simulation programs for combined conventional and V/STOL air traffic; and (5) develop air traffic control methods capable of handling aircraft at reasonable cost and at acceptable levels of safety.

II. GROUND TRANSPORTATION PROGRAMS

The programs will be undertaken primarily for UMTA against the requirement of the pressing public need for improved urban people movement in order to relieve congestion on city streets and highways. Ground Transportation System Development Programs will be conducted in all phases from conceptual design and analysis through hardware development, test, and demonstration. These programs involve improved utilization and flow control on existing highways (in support of FHWA), improved urban subway and commuter rail equipment (for UMTA including testing at DOT's Pueblo Facility), as well as new approaches to urban transportation such as TACV and Automatic "People Mover" Systems.

- *Program example 1:* PERSONAL RAPID TRANSIT

  PRT is a system of automated guideways, below and/or above ground, in which vehicles are part of the system. Typically, a traveler would go to the station in the city, enter a waiting vehicle, punch a destination code and be transported automatically and rapidly to his destination. The goals of the program include: (1) reduce traffic congestion; (2) eliminate pollution; (3) revitalization of urban cores; and (4) improve mobility of all citizens. The Center may be responsible for the following tasks: (1) identify social and personal costs and benefits of PRT installed in an urban environment; (2) derive cost functions for PRT technologies; (3) study the feasibility of PRT in various applications; (4) conduct demand analysis of proposed system; (5) simulate given or projected grid network for cities having various geometrical and flow patterns; and (6) simulate command and control strategies for system.

- *Program example 2:* URBAN CONGESTION

The goal of this program is to reduce overall travel time during rush hour by 25 percent in 50 urban areas by 1980 by improving traffic flow. Improved traffic plans for the cities will result in time saving to individuals, improve safety, reduce accidents and produce enormous productivity payoffs. Specific cost benefits include: (1) auto liability insurance cost reduced by 20 percent ($2 billion per year); and (2) reduce goods movement costs in cities by 5 percent ($1.5 billion/year reduction in a $30 billion/year goods movement bill). TSC may be responsible for the following tasks: (1) determine the housing, commercial, and industrial developments encouraged by, compatable with, or hampered by current urban transportation systems; (2) verify the potential economic benefits predicted with increased usage of public transit systems; (3) predict impact on public to toll, parking availability and pricing policies; (4) simulate an areawide traffic control system with sensors, computers, and auto and bus loading for a large city; (5) simulate a network of ramp access controlled freeways with priority access for buses in which the freeways are interconnected with bus priority; (6) determine the mix of dedicated streets and non-dedicated streets which will result in intermodal balancing so that free traffic flow will result; and (7) develop criteria and methods for establishing express and local bus routes which satisfy passenger demand.

III. MARINE TRANSPORT SYSTEMS

TSC will provide analytical support to the areas of harbor traffic control and navigation. These studies will rely heavily on TSC's capability in system analysis and simulation. They will have important ramifications in safety and in the reduction of oil pollution caused by tanker collision.

- *Program example:* VESSEL TRAFFIC SYSTEM
  The goal of this program will be to reduce maritime traffic accidents and the loss of life, property and that due to ecological damage by 60 percent by 1980. A savings of $206 million/year in avoidance of vessel damage, cargo and property losses and savings in cleanup costs of

oil and chemical spills and damage to the ecology will result when the program is completed. TSC will investigate vessel traffic separation procedures, navigation aids, centralized communications, traffic coordination centers and shore based radar surveillance with selected tracking and large scale displays of traffic movement.

IV. MULTI-MODAL TRANSPORT SYSTEM

The goal of a balanced National Transportation System places increasing importance on multi-modal transportation developments. To bring together best attributes of transportation by highway, rail, and fixed guideway automatic systems for the purpose of relieving highway congestion, the DOT has undertaken a dual mode development and demonstration in which TSC plays the major technical role. It is desirable to focus in a single organization the functions of planning, analysis, simulation, and technological engineering development which will be of value to all modes of transportation and to each modal administration. TSC is the logical organization to do this multi-modal work and, accordingly, will conduct programs in transportation technical assessment and multi-modal ground system component and technology developments, and will direct effort to such problems as cargo security and the economic and social impacts of transportation.

- *Program example:* DUAL MODE

  Dual Mode is a high capacity urban-suburban rapid transit system anticipated to be operational between 1990 and 2000. One concept of a dual mode system is that the dual mode vehicle would be privately owned and resemble a present day compact automobile. The vehicle would be capable of operating on roads and also on elevated guideways. Typically, a suburban traveler would manually drive his dual mode vehicle to the nearest collection station where the vehicle would be placed on a guideway. The traveler would then punch a destination code and be transported automatically to his destination. The dual mode concept is analogous to the personal rapid transit (PRT) system except that the dual mode traveler remains in his privately owned vehicle from his front door to the final destination point. The short range objectives of this program are to determine (1) technical feasibility, (2) cost effectiveness, (3) public need, and (4) system acceptance and implementation. The long range goals of the program are to reduce traffic congestion and eliminate pollution. Tasks in which TSC will be involved include: (1) develop short and long range plans for the development of an operational dual mode vehicle, including preparation of the necessary plans for the system analysis, development engineering, test and demonstration; (2) define a baseline dual mode system for specific future time frames for urban applications; (3) determine long range national interest in developing dual mode technology; (4) determine critical technologies and then economic benefits for application in a dual mode public demonstration; and (5) determine demonstration site location and develop plans for demonstration.

V. NOISE ABATEMENT

A major problem in the design of transportation systems is the impact of the system on non-users. The high noise levels of many transportation modes cause quite adverse environmental effects on the surrounding areas. Major emphasis in noise abatement will be placed on the analysis of right-of-way noise for the various transportation modes and for the development and demonstration of appropriate counter measures. These studies should serve both to reduce the existing noise burden associated with current systems and to aid in the design of new systems. It should be noted that without substantial quieting, most of the attractive new transportation systems would prove unacceptably noisy for the urban environment.

- *Program example:* AIRPORT NOISE REDUCTION
  The results derived from this program will provide a significant improvement in the airport noise environment and simultaneously increase capacity airports by reducing the noise level from individual aircraft by 4-20 EPN dB by 1976. Cost benefits of this program will include: (1) increased growth in air commerce with removal of constraints now imposed by noise; (2) reduction of airport development and modification costs by using available capacity at existing airports using quieter aircraft; (3) elimination of legal claims against airports which now total over $3.8 billion; and (4) increased trade balance from international fleet retrofit/replacement. TSC, other modal administrations, and NASA, will investigate new aircraft operational procedures, augment research and development leading to retrofitting of existing aircraft with accoustically treated engine installations, develop and quiet propulsion systems for future aircraft, and give financial support to accelerate replacement of existing aircraft with quieter new technology aircraft.

VI. POLLUTION REDUCTION

Currently 60 percent of all air pollution is transportation related. TSC's pollution reduction activities will be stepped across all modes in response to urgent concerns expressed by the OST and modal administrations. Analyses of particular pollution problems essential to the writing of new laws and regulations at all levels of government include the following: (1) an assessment of the environmental impact of high altitude aircraft (foreign and domestic); (2) development of safety standards for automotive parts as they impact on the leakage of exhaust gases into the passenger compartment; (3) development of surveillance techniques to detect and track oil spills; and (4) development of exhaust emissions monitors for marine engines. Naturally, much of the knowledge and technology gained in these studies will find application in the operational phase of future pollution abatement systems. The other major emphasis of the pollution reduction program is the development of low pollution propulsion technology, both in support of the Federal Advanced Automotive Power System Program and in non-automotive fields.

- *Program example:* CLEANER EFFICIENT POWER FOR SURFACE TRANSPORTATION

  The goal of this program is to reduce the energy demands of surface transportation vehicles and systems for fossil fuels by 1980 by 10 percent while maintaining low air pollution and noise emissions. The program cost benefits include: (1) reducing the national transportation fuel bill by $3 billion or more annually; and (2) slowing increase of fuel imports. This program will involve such actions as the development of advanced batteries for electrically powered vehicles, developing efficient motors and controls for vehicles using wayside power, evaluation of novel fuels for future vehicles, and improving the efficiency of heat engines.

VII. TRANSPORTATION SAFETY

In the field of air transportation safety, TSC will attack several problems which appear to be fairly readily solvable by electronic devices: (1) accoustical radar will be developed and demonstrated to warn pilots of wake vortices; (2) a microwave radiometer will be constructed and flight tested aboard airliners to give long range warning of clear air turbulence; and (3) bomb detection will receive the major emphasis in the antiskyjacking program.

Automotive safety can also be substantially improved by the development of a number of relatively simple electronic devices such as: (1) a crash sensor to activate air bags at the earliest possible moment; (2) driver performance testers to prevent drunken driving; (3) holographic, microwave or infrared non-destructive tiretesters; and (4) microwave grade crossing protection equipment. In all cases, demonstration of the device's life saving ability is the major objective.

As is the case with automobiles, the railroads appear to have several safety problems amenable to technological solutions. The unnoticed flaws in rails and wheels cause most derailments. These may be detected by a combination of magnetic, ultra-sonic, and x-ray devices. As for the rail accidents caused by human error, a cab recorder will be developed and tested to perform a function analogous to that played by the flight recorder in the investigation of air crashes. Data accumulated will also serve as the foundation for an analysis of the man-machine interface and for subsequent improvements in cab equipment design.

- *Program example:* RAIL-HIGHWAY INTERSECTION IMPROVEMENT PROGRAM

  The goal of this program is to reduce the number of deaths and injuries due to rail-highway grade crossing accidents by 50 percent by such actions as upgrading, eliminating or separating 50,000 rail-highway intersections. Benefits of this program include: (1) $8 billion savings in accident and traffic delay costs over 5 years; (2) savings of 900 lives and 2000 serious injuries each year; and (3) increasing the average rail speeds by eliminating the need to slow trains at grade crossing.

APPENDIX B

COMPUTER FACILITIES

I. IN-HOUSE EQUIPMENT

- IBM 7094 and 360/30

The 7094 with 1152K bits of core storage serves as a main processor in a system consisting of ten 7-track tape drives, one disk and an on-line printer. All pre- and post-processing is carried out by the 360/30 which is interfaced with a paper-tape punch and reader, a line printer, two magnetic tape drives and CALCOMP microfilm and pen plotters.

The 7094 is equipped with FORTRAN and COBOL compilers and operates only under batch control. The 360/30 operates under DOS, OS and PONY. The CALCOMP plotting system is a basic software package.

- DEC PDP-10

The PDP-10 is primarily being used as the main processor in ATC experiments. It has 2304K bits of core storage and an "add" time of 2.5 microseconds. Peripheral hardware includes two 7-track tape drives, DEC tapes, a card reader, line printer, two disk drives, numerous ASR-33/35 teletypes and an ARDS Display. A Bell System Data Station is utilized in the time-sharing of the system.

The PDP-10 is equipped with the following compilers, assemblers and processors: FORTRAN, COBOL, BASIC, ALGOL, MACRO, LISP and GASP II. These are available in either of the two modes--batch and timesharing.

In addition to the above-mentioned software, the PDP-10 is equipped with a Route Oriented Simulation System (ROSS) developed to provide a complete laboratory facility for experimenting with manual and automatic ATC procedures and mixtures of the two. A specially devised interface and communication software enables the simulation to be displayed by the DDP-516 on several consoles.

- HONEYWELL DDP-516

The DDP-516 has 512K bits, and "add" time of 1.92 microseconds and operates only in dedicated user mode. Input is initially from either the ASR-33 teletype or a paper tape reader. The system does have 1 disk drive for storage of data for future use.

The DDP-516 system is equipped with an ADDS 900 Graphical Display Generator which can be used to drive the available displays. In connection with this display subsystem, a Dynamic Display Software System (DISS) was developed on this DDP-516 for use in the interactive display of computer controlled flight information systems.

- HONEYWELL H832

The Honeywell H832 has 1024K bits of core storage with 1.7 microsecond "add" time. It is really a multiprocesso with two No. 632's back to back. It is equipped with all the necessary I/O devices and has a special data link to a DDP-516 in the lab. Both machines have FORTRAN compilers and assemblers as well as disk operating systems. The DDP-516 operates in both batch and timesharing modes.

This system is equipped with a large hardware package placed under the name of a Graphics Oriented Transportation [GOTS] System; the software to utilize this system also exists. The hardware package consists of the following:

(a) Display Generator attached to the DMC of the DDP-516
(b) A color CRT
(c) Three (3) CRT monochrome displays
(d) Light Pen
(e) Tablet and Stylus
(f) Joy Stick

The Display Subsystem Software consists of Internal Supervisor routines, External Supervisor routines, Light Pen Software and special purpose routines. Several small simulations have been written using the Display Subsystem but these were generally single isolated routines rater than general use software.

I. OUT-OF-HOUSE FACILITIES

- LINCOLN LABS

Lincoln Labs is currently operating under the burden of a daily backlog on its main computer facility, an IBM 360/67. This system has $8x10^6$ bits of core storage and an "add" time of 2.6 microseconds.

- MITRE

Mitre has recently upgraded to an IBM 370/155; this has reduced their current workload to two full shifts. The system has $5x10^6$ bits of core storage and an "add" time of 0.23 microseconds. Time is available on a third shift basis, but this will probably cease within the fiscal year.

- SAO

Smithsonian Astrophysical Observatory operates a CDC 6400 in batch mode only; this is a definite disadvantage to a real-time simulation facility.

- AVCO CORPORATION

Avco Corporation operates a facility equipped wit an IBM 360/75 with core storage of $8x10^6$ bits and an "add" time of 1.6 microseconds. They currently do not support any timesharing operations and do not plan to expand into this area. They do have microfilm plotter capabilities, but very little is known about their system.

- DRAPER LABORATORIES

Draper Labs, with a 360/75 expects to add more hardware and software to their system which currently has $4x10^6$ bits of core storage. With the completion of the NASA

Apollo Program in January, Draper Labs will have an additional 300 to 400 hours per month available to users; this will primarily be on a second and third shift basis.

- CYBERNET

Cybernet, a commercial organization, is equipped with a CDC 6600 which has tremendous core storage, time-sharing facilities and a cycle time of 0.3 microseconds. The teleprocessing lines from Cybernet transmit at a rate which barely keeps a slow speed printer operating and would definitely not be able to update a display screen fast enough to satisfy the smallest dynamic picture.

III. INTERNAL DOT FACILITIES

A search of the available literature on government computational facilities has revealed that DOT has very little along the lines of large-scale computing machinery. Their largest single model is a 360/65, while they have several 9020 systems, i.e., 360/50, ponied back to back for multiprocessing; these 9020's are located at the FAA center in New Jersey.

APPENDIX C

GLOSSARY

Term or Mnemonic	Definition
A&E	Architecture and engineering
ADP	Automatic data processing; data processing requiring minimum human assistance
Alphanumeric	Characters that include the alphabet, numerals, and other symbols such as punctuation or mathematical symbols
Analog	Representation of numerical quantities by physical variables (continuous) e.g. notation, volume change, etc.
A/D or D/A	Analog/Digital (A/D) or Digital/Analog (D/A) converter which performs fast data conversion between digital and analog computers
ARPA	Advanced Research Projects Agency
ATC	Air traffic control
Batch	Group of records or data to be taken as a whole
CPU	Central processing unit
Data Reduction	Transformation of masses of raw data into useful or simplified intelligence
Demographic Data	Census data
Digital	Discreet data (discontinuous) e.g. series of arithmetic computations
Documentation Processing	Collecting, organizing, storing, citing, and dispensing of documents or their information
DOT	Department of Transportation
Emer. Med. Services	Emergency Medical Services

Term or Mnemonic	Definition
EPN dB	Effective perceived noise level (in decibels) includes time exposed to noise as well as loudness
Fast-time Simulation	Computer speeds up time elapsed to allow for more efficient simulation, e.g. an event taking 20 minutes in real time may be scaled to take 20 seconds of simulation
FHWA	Federal Highway Administration
GFE	Government Funded Equipment
Graphics Input	Data input in form of charts, graphs, etc.
Graphics Output	Data output in physical form e.g. graphs, charts, etc.
Hardcopy	Typewritten or printed characters on paper, produced at the same time data is turned into machine language that is readily comprehensible e.g. printed reports, summaries, lists, etc.
HW	Highway
I/O Input/Output	Information or data to or from computer
Interactive Computation	Direct communication with computer
Interactive Graphics	Physical representation of data viewed as a program is running; can be both input and output terminal
JOD	Joint Occupancy Date
Large Scale Display	Visible representation of data on a large scale
Library Service	Organized collection of standard, checked out routines

GLOSSARY (Continued)

Term or Mnemonic	Definition
M&O	Maintenance and Operation
Management Information (system)	Specific data processing system designed to furnish management and supervisory personnel with information consisting of data that are desired and which are fresh or with real-time speed
Mass Storage	Installations to provide efficient and effective storage of masses of data
Modeling	Characterization of a process, object or concept in terms of mathematics enabling relatively simple manipulation of variables
NAFEC	National Aviation Facility Experimental Center
NASA	National Aeronautics and Space Administration
OMB	Office of Management and Budget
Optical Character Recognition	Identification of graphic characters by photosensitive devices
OST	Office of the Secretary of Transportation
PRT	Personal Rapid Transit
Remote Access	Obtaining data or placing data in storage from a terminal not located at the computer
Real-time Simulation	Model where time elapsed exactly corresponds to time sequence in real-world events
Sensor Implementation	Implementation of device allowing computer to obtain analog information concerning temperature, flows, pressure, etc.
Simulation	A system operating by means of mathematical or physical models that operate on real-world or specifically designed problems in a time-sequential method similar to the system itself

GLOSSARY (Continued)

Term or Mnemonic	Definition
TACV	Tracked Air Cushioned Vehicle
TASF	Transportation Analysis Simulation Facility
TASS	Transportation Analysis Simulation System
Telecommunications	Transmission or reception of signals, writing, sounds, or intelligence of any nature by wire, radio, light beam or any other electromagnetic means
TLV	Tracked Levitated Vehicles
TSC	Transportation Systems Center
TST	Office of the Assistant Secretary for Systems Development and Technology
UMTA	Urban Mass Transportation Administration
V/STOL	Vertical short take-off and landing aircraft