TRANSPORTATION AND THE FUTURE

JANUARY 1979

U.S. DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
ASSISTANT SECRETARY FOR GOVERNMENTAL AFFAIRS

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Preface

This report is an introductory overview of currently emerging and future technological developments in transportation. Designed primarily for officials in state and local governments, we have tried to write the report to be comprehensible and useful to an intelligent non-technical audience. We have tried to make treatment of the topic relatively comprehensive, but have provided extra detail on technologies of special interest to these officials. We have also tended to be somewhat conservative in our treatment of these topics in the belief that it is better to make promises which can be kept than to raise false hopes which cannot be met at present.

The document is not, and should not be considered to be, a study of alternative transportation futures. In such a study, a coherent set of alternative socioeconomic assumptions is presented, and future transportation developments and the impacts which result from them are traced. Under some socioeconomic circumstances, transportation events will occur that will not occur under others. A good number of these alternative events will result from policy choices made by state and local officials.

The majority of the technologies described here will be applied over the next ten to twenty years. However, some of the technologies, such as hydrogen-fueled hypersonic transports and tracked levitated vehicles, will not be introduced commercially in this century. In addition, there typically are demonstrations or pilot tests of new technologies before they enter general applicability.

It should especially be noted that nontechnical and institutional factors frequently have more impact on the ultimate implementability of an innovation than pure technical feasibility. This should be taken into account in considering any of the options described here.

Summary

The characteristics of future transportation systems will be determined in large part by the missions they have to serve, and by the broad environment which they will be entering. Demographic shifts place added emphasis on automated systems because of a decreasing labor pool of young and middle aged Americans, and on systems to serve low-density, suburban, and rural areas. Energy constraints may make electrically powered systems more attractive.

Whatever America's urban future, future urban transportation systems will probably consist of a mix of transportation options working together. These systems will include technologically upgraded versions of existing options, as well as new options like personal rapid transit (PRT) or dual mode. Bus systems to serve rural or exurban areas are also developing, and may be tied into evolving urban systems.

The passenger automobile, or some option like it, will probably retain dominance of the transportation scene. Its flexibility and personally tailored service are unrivaled by any common-carrier options currently known. However, design changes have already begun to make the car more fuel efficient, and new engine technologies also appear promising in the longer term (Post-1985).

Energy shortages may necessitate more reliance on intercity rail systems with buses serving lower density routes. After the turn of the century, tracked levitated vehicles (TLV's) may supplant the high speed trains operating on some high density routes. Energy efficient jet transports and new short-range, short takeoff aircraft should be entering service in the 1980's. Supersonic, hypersonic and lighter-than-air aircraft may also have long-term applicability.

Cargo systems will also evolve. Trucks have begun to grow larger and to incorporate modifications to make them more energy efficient. Containerization and automated freight handling should improve their compatability with rail and air freight systems. Nuclear power freighters and tankers may appear on sea routes, with inland vessels or barges carried like intermodal containers. New pipeline technologies are also emerging.

The space shuttle will enter service in the early 1980's, and make major changes in the way orbital missions are approached. Construction projects in orbit become much more feasible including such concepts as solar collection satellites or space manufacturing centers.

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Chapter 1: The Transportation Environment

I. Introduction

It is always difficult to speculate intelligently or accurately about the future, especially in an area as sensitive to technological change as transportation. Historically, many transportation technologies have risen, had extensive periods of application, and declined as new systems took their place. In some cases, such as highways, breakthroughs in construction techniques and in new types of vehicles allowed the system to continue to grow. In other instances, such as canals, competition for more effective and efficient modes for the same mission lead to obsolescence and ultimate decline. The history of transportation is a history of how to apply (or not to apply) technologies.

A tremendous number of economic, sociological and technical factors interact to determine whether a new technology will persist. However, if one lesson can be learned from transportation history, it might be that the application of any new technology has to fit the mission defined for it. The personal helicopter, the flying platform, and automobiles which would convert into airplanes were all proposed but failed to gain any widespread popular acceptance because of such mismatches.

As a technology evolves, it then has to be fully developed and tested before it is deployed, or it might not be able to meet the claims of its proponents. The British Comet Jetliner was introduced in the early 1950's, but it met with only limited success because of structural problems. It was not until the Boeing 707, an adaptation of the proven U.S. military KC-135 tanker, entered service in the late 1950's that turbine-powered airliners really were accepted as a practical alternative. From that point, it took less than ten years until jets essentially attained dominance of the entire field of commercial aviation. The quick adoption of turbine powerplants in commerical aviation points up the pervasive impact of a true "breakthrough."

Of course, the broader environment that any innovation is entering also has a lot to do with its subsequent "acceptance" or lack thereof. Technicians have not been particularly successful in forecasting future value systems or standards, and these values set the bench marks by which new systems are judged. However, we can safely say that transportation must be a good neighbor, and compete favorably with other choices for investment.

Many of the factors shaping the transportation system of the future have already emerged, and will have more profound effects over the next twenty to thirty years. Although not immediately connected with transportation itself, these broad concerns determine the missions of future systems, their technical practicality, and economic feasibility. Some of the major trends will be discussed in the following sections.

II. General Demographics

The majority of the people who will be adults in the early 2000's have already been born, so it is possible to make some general statements about population during that period. This discussion focuses on trends in the United States, which has been approaching zero population growth, and might be viewed as setting some of the "lower bounds" for world population.

If population grows consistent with Census series III projections (1.7 children per female through the year 2000), the U.S. population should stabilize near some 250 million in the late 1990's (Ref. 56). Shortly thereafter, a major shift in the available labor force should occur as the people born in the rapid population growth period 1945-55 begin to retire. With these assumptions, the proportion of people over 65 will increase to some 16 percent of total population, by the early 2000's, as compared to the 10 percent of total U.S. population in the 1970's.

A population growth spurt in the late part of this century might blunt this shift effect somewhat, but there still should be some increase in the relative number of elderly. This spurt may result if the recent lowered birth rates came from decisions to defer having children, rather than not to have them at all. An increased retirement age (70-75) might also blunt the economic effects of the trends.

Geographically, demographers have noted a major migration to the "sunbelt" states of the south and southeast. Especially in the southeast, water and resources are plentiful, making these states attractive as new manufacturing centers. The warm climate of these states has also made them attractive as winter retirement communities. There is strong evidence the trend will continue, especially noting the increasing proportion of elderly people in the population. Some observers have also pointed out a migration from inland areas to coastal zones, but this shift has not been as precisely defined as the sunbelt trend noted.

Simultaneously, there have been some basic changes in the pattern of urbanization which has taken place over the last hundred years. The early 1970's indicated a major resurgence of growth in rural areas. Much of this growth has occurred in so-called "contiguous" counties to major urban areas, suggesting this development might more properly be described as "exurban," rather than truly "rural." However, there have also been growth increases in many free-standing small towns and smaller urban areas. Interviews with people who have moved out of major urban centers frequently indicated dissatisfaction with the pace and life style of the larger cities, and a general uneasiness about the effectiveness of large scale institutions in dealing with urban problems (Ref. 28).

This is not to suggest that the urban-suburban life style which dominated the middle part of this century in industrial nations is collapsing; a tremendous amount of capital has already been invested and these facilities and housing will persist. In addition, some cities are going through what has been called "gentrification", as some middle and upper income people are moving back to center city areas, often in refurbished townhouses or older buildings. Even when growth occurs in low-density areas, there always seems to be some form of intercity transportation available to link up these small towns with the larger urban complexes. These increasingly complex demographic trends imply an added level of technical sophistication to meet the travel requirements of the low-density areas and the more complex development patterns they have spawned.

Other recent important demographic factors may have transportation implications. Illegal immigration, much of it caused by rapid population growth and unemployment in Mexico, is making a large but not well-measured contribution to U.S. population growth. A reversal of this trend either because of improving economic conditions in Mexico or stiff enforcement of U.S. immigration and employment laws, would accelerate the present trend toward zero population growth.

Recent court decisions liberalizing abortion laws have significantly reduced the natural population increase. Success of political efforts to make abortions more difficult to obtain is a factor that could reverse the current trend toward a lower birth rate. Births to teenaged mothers now account for a significant part of the natural population increase; current Federal programs aimed at improving young people's knowledge of birth control techniques could further cut population growth.

The U.S. death rate is now at its lowest point in history, primarily because of a decline in deaths resulting from heart disease, stroke and traffic accidents. There is every indication that it will decrease still more as the causes of another leading killer, cancer, become better understood. The various possible combinations of outcomes of these forces would each have their transportation implications.

III. Energy and Resources

The U.S. transportation system, particularly its highway elements, has been set in place during an era when tapped energy sources were plentiful and prices were low. Transportation was a necessary feature for wide-ranging development patterns. Such a spatial structure may be affected more by energy shortages than transportation systems in older countries, where tighter development patterns are typical. There is a general realization now that many of the key energy sources on which highway-based transport systems are based have finite limits. As such, the whole issue of energy supply may place constraints on the paths open for future evolution of urban, inter-regional and national transportation sytems.

Since the course that future transportation systems (and society in general) will take is heavily dependent on energy and resource availability, it might be well to examine the subject with this as a major variable. Three general scenarios appear possible:

1. Business as Usual, in which transportation would become ever more rapid, convenient and personal, and population more dispersed, based on a continued availability of cheap liquid fuel. (This scenario, while possible, is viewed as improbable by many policy makers.)

2. Successful Transition, in which energy sources are switched gradually from petroleum as its price rises. It also implies heavy dependence on coal or nuclear generated electricity in the next 10-20 years, and significant rearrangements in urban and suburban ways of life.

3. Restricted Supplies, in which energy costs rise drastically because of a great lag in substitute sources. Associated with this would be total and per capita energy use decreases, and massive changes in transportation and societal organization as the nation readjusts, painfully but successfully.

These scenarios, which cover a range of plausible outcomes, have dramatically different transportation futures associated with them. For example, barring some major technological breakthrough such as nuclear fusion or substantial cost reductions in solar capture technology, energy under a restricted supply scenario could cost substantially more. These costs would have to be passed on to its consumers. Costs could include both increases in the prices of conventional petroleum sources as competition for them becomes more intense, and capital costs associated with the construction or installation of new facilities designed to utilize energy from non-petroleum sources. Such projects might include retrofitting electric plants to burn coal, installation of solar collectors or heaters, and large-scale deployment of nuclear fission or fusion powerplants.

With the changing energy situation, electrically powered transportation systems could assume an added importance. An electrically powered system does not have to depend on oil, natural gas, or petrochemicals, since a number of techniques can be used for power generation. Some of the possible alternative power sources, which could be keys to successful transition, include the following:

1. coal and similar non-petroleum fossil fuels
2. alternative alcohol-based fuels (methanol/ethanol)
3. synthetic fuels (oil shale and tar sands)
4. hydrogen as a fuel
5. solar heat (focusing sun's rays to generate heat in some working fluid)
6. solar photovoltaic (collecting array of solar cells)
7. nuclear fission
8. nuclear fusion (if perfected)
9. geothermal power

10. hydroelectric power
11. tidal power
12. ocean temperature differential power
13. wind power

Electrically powered systems thus are potentially less sensitive to disruptions in the availability of any particular type of fuel. Of course, such electric-based systems still have to compete with all other uses for power available through national grids. Taking a broader view, electrical systems still compete with alternatively fueled systems, including those using hybrid fuels, in the demand for shale, tar sands, and coal.

Energy shortages may also influence the pattern of national development over the next few years. For example, in the United States the migration to sunbelt states may be affected if price increases or controls make use of home air conditioning equipment prohibitive. In the North, shortages of heating fuels may have similar effects. On a smaller scale, energy shortages may force a return to tighter urban centers if it becomes prohibitive to provide services over the broad areas noted today. This latter prospect has contributed to renewal of interest in downtown revitalization, and higher density development patterns.

There are also limits to the world reserves of a number of important minerals and metals. The United States imports a significant quantity of several materials in this category. There is heavy dependence on foreign sources for bauxite, chromium, platinum, rubber, tin, zinc, cobalt, and mercury. However, there is little current evidence that cartels, such as those which formed among oil suppliers, will develop for any of these materials, or that any major shortages or large price increases should occur before 1990. Beyond 1990, material scarcity may have an increasing impact on technical choices, and make some technologies which are based on the use of more plentiful materials attractive (Ref. 46). In addition, new classes of materials, now in the process of development, may be useful.

IV. Economic Implications

There is no current indication of any major lessening in the rate of inflation, either in the U.S. or on a world-wide scale. If this remains true, major transportation system investments in the future will require multiple billions of dollars. At the same time, many authorities have noted a developing need for investment capital across all sectors of the economy. Proposed transportation improvements will have to compete for this capital, along with requirements in all the other sectors of the economy.

This scarcity of capital may be complicated by the changing demographic balance of the world population. For example, with the increasing proportion of elderly people to working people in the United States economy after the year 2000, a major increase in productivity of the available work force is called for. To achieve these productivity increases, major infusions of capital to install automated technologies may be needed. Resolving the competition for the available capital among the various investment needs could be one of the more crucial economic problems in the latter part of the twentieth century.

V. Transportation - Telecommunications Tradeoff

In the long term, advances in telecommunications technology may have a substantial impact on the path of evolution that transportation takes. For example, a continuation of the current pace of technological improvement in telecommunications might decrease the demand for transportation to and from the work place by permitting a significant number of workers in information-related business to work at home or in remote centers. Some signs of the feasibility of this approach include the evolution of the home television set into a display for home computer terminals and monitor for playback of videotapes or videodiscs. Home televisions may eventually even serve as receiving stations for direct transmissions from satellites. If socialization functions of jobs are key, local work centers "linked" to central communication complexes are especially probable. A wide variety of possibilities are open.

The effect of these changes on travel demand is a subject of much speculation. Some commentators argue that telecommunications improvements will eliminate the need for certain types of business travel. On the other hand, some analysts believe telecommunications improvements will stimulate the demand for travel by making U.S. society more closely knit, and promoting personal and non-business trips.

The U.S. Postal Service may eventually use electronic communications instead of physical transportation of paper to transmit some types of messages between cities. Telecopiers are already in widespread use, and this is merely an extension of the trend. If electronic mail did enter widespread use, it might mean a long-term reduction in the growth of air cargo.

VI. User Perceptions and Attitudes

The opinions and views of individual Americans will have a lot to do with the acceptance of new systems and options. The Department recently conducted a major survey of American attitudes toward transportation. This study provided some basic indications of what kinds of changes and evolutionary developments would be accepted by the American public.

In general, the public expects some basic changes to occur in the national way of life over the next few years. They favor proposals which increase the number of transportation options open to them, and have a strong distaste for "mandatory" solutions such as gas rationing. There is a strong consensus that the auto must be used in a more energy-conscious way.

The American people also seem to support additional investments in public transportation relative to highways. There are indications that trying more innovative concepts of transit service, like park-and-ride buses, would be especially well received. There also appears to be significant potential for carpooling, especially if special treatment is given to multi-rider cars on the streets to cut travel time.

Over the long term, these perceptions and judgements may change. However, these kinds of public acceptance considerations should be factored into the planning for any future systems. An expanded summary of the survey discussed here is included in the DOT document Through Their Eyes, Part II: The People Speak.

Chapter 2: Urban Public Transportation

I. Urban Environments

Urban transportation requirements in the future will be determined in large part by the operational environments which they will have to serve and function in. The public transportation system needed to serve a spread-out, heavily suburbanized metropolis is quite different, technologically, from that needed to serve a very dense, centralized urban complex. There are a number of plausible urban futures, each having its own unique set of transportation problems and system requirements. Some of these futures include the following:

A. Urban Decline.

There has been a pattern of decline noted at the core of many large size cities. If it were established that such a condition was irreversible, there might be a conscious decision to let large center cities continue to decline, and to emphasize service to close-in dense areas and suburban activity centers. The result of this policy would be a donut-like cluster of population and business concentrations, with its center essentially abandoned. This future is not particularly desirable because of its major loss of fixed facilities this could imply, and the end, in most places, of the downtown-cosmopolitan life style. As a result, this policy is somewhat unlikely unless major resource shortages forced it.

B. Urban Revitalization

Many urban planners hold that the downtown decline pattern is reversible. If this view is accepted by political leaders, there might be policy initiatives to encourage revitalization of, and new development in, downtown areas, coupled with programs to make the center city life style more attractive. The end result of such initiatives would be dense, compact cities with higher populations and a much greater need for good circulation systems than current urban centers. Eventually, some cities could even evolve into "megastructures," with all the inhabitants living in one huge complex of interconnected buildings. There are complex design problems associated with this approach, but its proponents find this life style attractive and claim there is a potential for major energy savings by supporting this developmental concept.

C. Continued Current Trends.

The most likely urban development alternative is a hybrid between the two above approaches. In that case, major efforts would be made to save the center city, but suburban growth would continue to occur. In effect, this policy projects a continuation of current growth trends, but with some improvement in downtown conditions and a greater integration of downtown and suburban activities. Regional transportation is especially important if this occurs, since people would begin to view the center city as an activity center they wanted to use again.

D. Urban Decentralization.

Another possibility is a growth spurt in small and medium size cities taking up most of the national population growth, with some contraction of large cities towards their centers as population loss occurs. In the United States, this trend may be especially important if people leave large cities in the Northeast to resettle in the South or West. This spreading out of population would imply more emphasis on short-range, medium capacity systems and circulation requirements. It also would require more sophisticated telecommunications networks to transmit data between the various centers, and to lessen the need for routine long-distance business travel.

Because of variations in local policies, all of these scenarios may manifest to some degree, the specific course of evolution for any city being determined by local conditions and policy decisions.

II. System Options

Urban transportation planners have a wide variety of options to choose from, each having its own cost and operational characteristics, and capable of providing specific types of service.

A. Paratransit systems.

Paratransit is a general term for the spectrum of options between the conventional taxi and full-size (40-50 passenger) buses. These services include (among others) shared-ride taxis, carpools and vanpools, jitneys, subscription buses, and demand-responsive buses. For many of these alternatives, operating policies can be varied to adjust service to changing travel patterns and demand over the day. Paratransit elements thus enable an operator to provide special, personalized service in areas where it would otherwise be impossible. They should be a key component of future urban systems, especially in lower density areas (Ref. 61).

At least three major applications for paratransit options can be identified in the future. First, paratransit, especially dial-a-ride or demand-responsive service, shows great promise of extending transit service to lower density suburban areas of large cities. These flexibile-route buses can serve low levels of travel demand far more economically than extending conventional fixed route bus transit too far into the suburbs.

Second, paratransit can be used to provide circulation service in dense downtown areas. Typical of this type of operation are jitneys, small vehicles which run over fixed routes downtown and can be hailed by passengers anywhere along the route. Jitneys are being used successfully in such cities as Mexico City and Manila, but local regulations prevent their implementation in many cities here. Fixed route circulation minibuses, such as Washington, D.C.'s Downtowner Service, operate in a similar manner, and merely substitute conventional bus stops for the hailing technique.

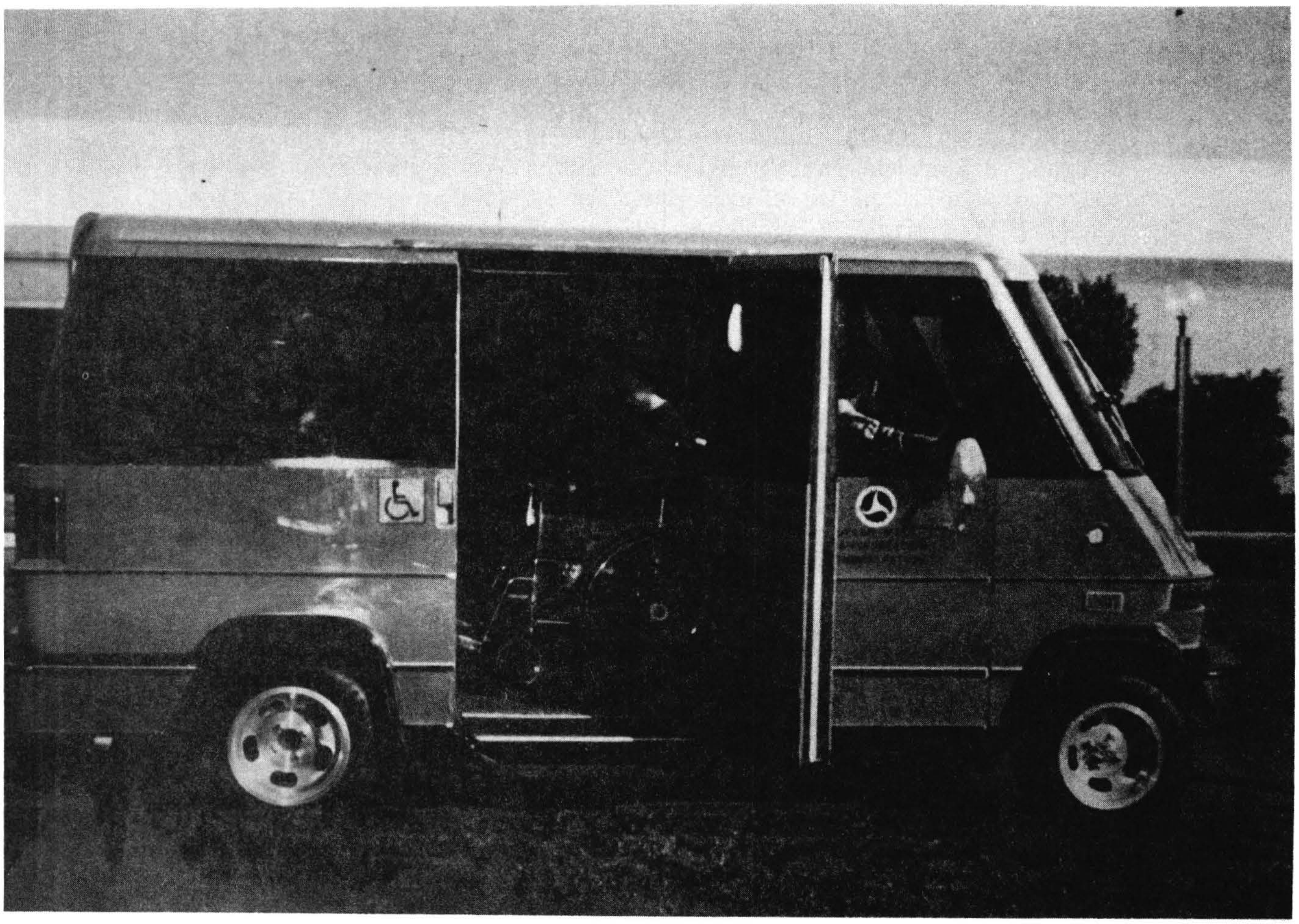

Figure 1. Paratransit vehicles like this prototype may find extensive use in future cities and suburbs.

Finally, paratransit can be used to provide special transportation services to groups like the handicapped or elderly. For these applications, special modifications like extra-wide doors, lifts for wheelchairs, and special seating configurations may be necessary. It is also desirable for the drivers of vehicles in these applications to have some special training or instructions on the problems of such mobility-limited users (Ref. 73).

Future paratransit services in large urban areas will probably make extensive use of computer routing and dispatch services, both in configuring services to particular needs of their own coverage areas, and tying these services into line-haul bus or rail operations which cover the entire region. Computer applications do not appear to be as critical for smaller-scale (12 or fewer vehicles) systems. Radio communications will probably be commonplace, and may be either on a voice or digital basis.

The vehicles themselves will evolve to fit their specific applications, but it is almost certain that more fuel-efficient engines with lower maintenance requirements are needed. There have been some experiments with battery-powered buses, but major applicability of this approach depends on a breakthrough in low-weight, effective batteries. The brakes and suspension system have also proven to be critical areas in the paratransit vehicles operating in the mid-1970's, and will require improvement.

B. Line-haul Buses.

The full-size 40 to 50 passenger bus is the mainstay of most conventional transit sytems, and there is much evidence that this dominance will continue. Because of the extensive highway network already in place, conventional bus service can access almost any point in the densely populated metropolitan areas. In downtown areas, these systems can run at capacities of some 10,000 passengers per hour per lane. Capacity ranges up to some 25,000 passengers per hour per lane are possible with express bus operations on exclusive lanes or busways.

At low demand levels, it becomes uneconomical to provide full-size conventional bus services and a transfer to a local minibus-based paratransit service becomes desirable below some threshold usage. Research at the U.S. Department of Transportation's Systems Center indicates this transition level is approximately 100 passengers per square mile per hour, if twenty passenger minibuses and fifty passenger transit vehicles are being considered for the service.

The ability to link transit and paratransit services may lead to the rise of cooperative regional-coverage bus systems. In such systems, the suburbs and special users would be served by paratransit, downtown areas and activity corridors by fixed route transit, and express transit on exclusive lanes would link suburban activity centers and downtown. As part of automated traffic control, signals may be programmed to give priority to transit vehicles over conventional auto traffic, thereby speeding bus flow.

The Urban Mass Transportation Administration's Office of Technology Development and Deployment has given special attention to increasing the safety, comfort, efficiency and public acceptability of buses. Important goals, which resulted in the development of a standardized full-size modern bus, or Transbus, were also reduction of fuel consumption, improvement of air quality, and accommodation of the elderly and handicapped.

There may also be a shift to larger-size buses, especially if a recentralization trend occurs downtown or suburban activity centers become more dense. Such service could be provided by "double-deck" buses such as those currently found in London, or

Figure 2. Some cities have experimented with transit malls, such as this one in Minneapolis, Minnesota.

by long, articulated buses with a flexible center section. Both approaches are currently under consideration for wider application, and the "superbus," as it is colloquially called, may be a common feature in tomorrow's cities.

C. Light Rail Systems.

For higher capacity systems, cities may consider light rail transit. Light rail transit is a descendent of the old trolley system technology, and many systems have continued to operate in Europe. Typically, electrically propelled light rail vehicles operate singly or in short trains. Most of the right-of-way is typically reserved or grade-separated, but these systems can also operate at-grade, mixing with highway traffic. This latter case is especially prevalent in the European systems. However, grade separation is viewed by many U.S. planners as the distinguishing feature of modern light rail. Such systems usually run under the control of the vehicle's operator and are not automated.

Light rail systems can also be deployed as the first step in the eventual upgrading to a full-scale, high capacity rapid rail line. When deployed for this purpose, several design changes are made from conventional light rail systems, including greater radii of curvature on the guideway, less severe grades, and provisions for later installation of power distribution, control, and platform facilities typical of full-scale rapid transit (Refs. 62, 72).

D. Rapid Transit or Heavy Rail Systems.

Rapid transit systems are considered for the highest urban transportation line capacity levels, up to some 40,000 passengers per line per hour. These systems can either operate with steel wheels on steel rails, as is typical with most U.S. rail lines, or the vehicles may have rubber tires and operate in a concrete channel, as with the Montreal, Canada or Paris, France systems.

As with the bus systems, two major applications are typical. Grid networks downtown can help provide circulation service at high capacity levels. Stations are usually closely spaced, and interstation speeds are relatively low since there is little time to accelerate before braking for the next stop. The downtown segments of Washington, D.C.'s METRO system are built like this. Radial lines may also extend from the downtown into the suburbs along high density corridors to serve commuter traffic. Station spacing for this application is greater, and speeds are usually higher. San Francisco's Bay Area Rapid Transit (BART) System typifies this latter, commuter-oriented design.

Rapid rail and other fixed guideway systems are frequently proposed because of their impacts on local development, including the siting of high-rise buildings or business complexes near stations. However, it is unclear whether this development is stimulated by the rail stations or merely a spatial reallocation of development which would have occurred anyway. Local zoning and parallel community planning do seem to have a major impact on the success of such policies. In addition, there is always some economic stimulation effect associated with deployment of rapid rail, just as there is with any major public works project (Ref. 55).

Future rapid rail systems may depend heavily on automation both for train control and for support services like fare collecting. If regional coverage transit systems become a reality, there should also be much closer ties between those rail elements and local feeder systems, requiring better coordination of scheduling between the two.

To improve the energy performance of rail systems, vehicles may be equipped with flywheel energy storage systems. The flywheels are activated as the vehicle brakes, and the energy stored is then used to help the system accelerate after the stop is completed. The U.S. Urban Mass Transportation Administration's Advanced Concept Train (ACT-1) uses this approach (Ref. 71). An electrical regeneration approach, where the vehicle's kinetic energy (energy of motion) is converted to electricity and fed back into distribution lines for use by other trains, is another possibility.

E. Horizontal Elevators

The rise of automated control technologies has made possible a whole new family of urban transportation sytems. Typically referred to as horizontal elevators or people movers, this set of options may provide high line capacities while at the same time providing personally tailored service. There are three levels of sophistication in this technology, differentiated by network complexity and control sophistication. (Ref. 59).

Figure 3. This people mover in Morgantown, West Virginia is used to link parts of the campus of West Virginia University.

The simplest kind of horizontal elevator is shuttle and loop transit (SLT). Large multiple-passenger vehicles, often with standees, run back and forth between several stations along a single path (shuttle), or along a closed path between the stations (loop). There are usually no extensive side spurs or branchlines requiring switching. The first deployments of these systems have typically served a circulation function at airports or in activity centers, or shuttle between a number of proximate activity centers (shopping complexes, amusement parks and the like). Guideways are typically short, and headways (times between vehicles) are relatively long, up to a minute or more. The monorails found at some amusement parks are typical of this application.

The next level of complexity is Group Rapid Transit (GRT), which uses medium-size vehicles carrying groups of 12 to 70 people. Group Rapid Transit systems generally have more extensive networks than SLT systems. Switching capability is added, so the networks of GRT systems have some branches and spurs for off-line loading, thereby shortening enroute delays. Because of slow switching, monorails are unlikely to be used in these applications. Headways can range from 3 to 60 seconds. Service either can be scheduled, or limited nonstop origin-to-destination trips can also be provided. The systems in Morgantown, West Virginia and at the Dallas-Fort Worth Airport are typical applications of this technology (Ref. 65).

The third level of sophistication is represented by true personal rapid transit or PRT systems. Added technical sophistication in PRT systems includes much more complex and extensive networks than GRT, smaller vehicles, and more complex control sytems. True PRT, in its evolved state, would consist of small 2-6 passenger-carrying cars operating on an exclusive guideway under computer control. This guideway could be either elevated or placed at grade level, and might even be integrated into some major buildings.

To use a PRT system, the passenger would first specify the trip's origin and destination, probably using a push button to enter it into the control system. A car is then automatically summoned, and proceeds to take the user there non-stop: service is personally tailored. To keep system performance up (so as not to degrade line capacities or individual travel times), all boarding and disembarking would be done on a side spur which does not obstruct the main line. Headways can be extremely short, from 0.2 to 3 seconds. This type of system looks especially promising if center city cores can be successfully revitalized (Ref. 55).

The principal costs of any of these horizontal elevator systems are their guideway construction expenses, amounting to 50-70% of total capital cost.

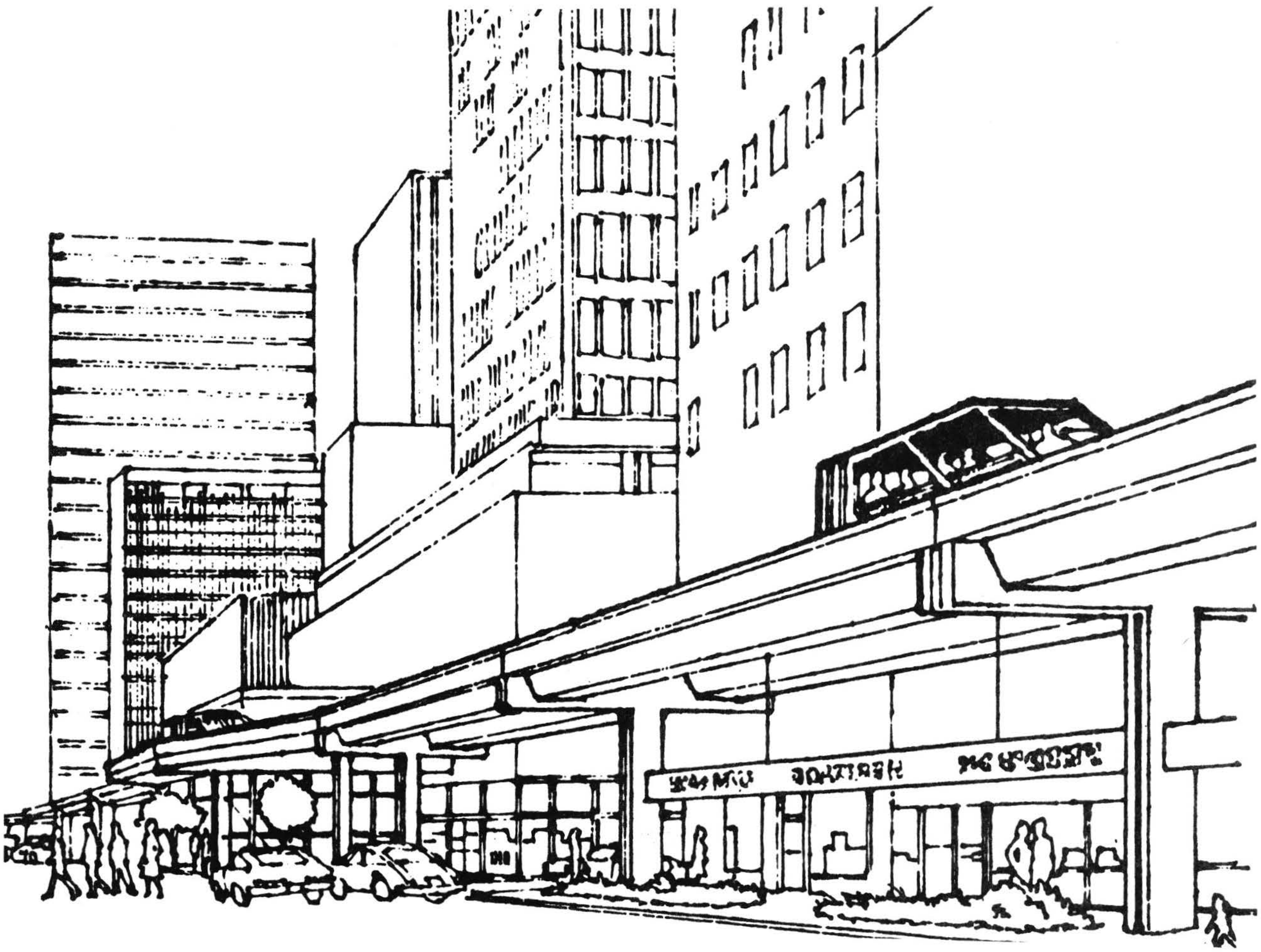

Figure 4. This is an artist's concept of an operational downtown people mover (DPM).

The Urban Mass Transportation Administration's Downtown People Mover (or DPM) Program will provide several urban sites with capital assistance for the preliminary engineering, construction, and initial public operation of fully automated guideway transit systems in downtown environments. The program is intended to show that fully automated, relatively simple SLT type systems can be reliable urban transit alternatives that provide adequate service at a reasonable cost.

This program also responds to one of the broader goals of UMTA, which is to support the effective economic functioning of the central cities. The DPM program will provide operating data, planning tools, and experience that other cities can use in solving their transportation needs for downtown circulation systems. If such systems can be proven reliable, safe, and economical, they could become imaginative solutions to the local circulation problems in congested downtown areas and serve as a revitalizing force for urban centers.

The capacity of the proposed DPM systems are in the range of 6,000 to 18,000 passengers per lane per hour. The larger passenger capacities can be accommodated by using trains of two or more vehicles coupled together.

F. Dual Mode Transit.

Operational dual mode systems would represent the ultimate reconciliation of personal transportation needs with the benefits of a public system. As currently conceived, dual-mode vehicles would be able to run under operator control on conventional highways, then switch onto a special guideway for operation under computer control. At least four approaches to the concept have been proposed:

1. The Interactive Road-Vehicle system, where today's traffic control devices would evolve on some urban roads to the point where they not only pass information to the driver, but also actually control the vehicles themselves. Automobiles would have to be equipped with special sensors, receivers, brakes, steering and engine controls to operate on such road segments. Such a system would evolve over a period of years, as highways were equipped with required control equipment and vehicles with the necessary subsystems entered the fleet (Ref. 56).

2. The Pallet System, where conventional automotive vehicles would be driven onto flatcar-like pallets, each with its own propulsion system and controls tied directly to a special system guideway. After the car was fastened on the pallet, it would move off under system control to its destination. Such a system could be used by practically any car, but the capacity limitations and time delays associated with loading and unloading compromise its benefits somewhat (Ref. 64).

3. The Dual-Mode bus system functionally is identical to a dial-a-ride or demand-responsive system, except that a dual-mode bus mounts a limited-access, high-speed guideway for the line-haul portion of its trip, gaining a time advantage. This also allows the vehicle to draw power from the guideways, and increases the capacity of the line-haul segment. However, it does assume that some clustering of user destinations occurs in the final distribution portion of the trip for the riders on any particular bus (Ref. 64).

4. The Small Personal Vehicle (SPV) system is one in which small, electrically powered cars are rented by users of the system. Such a system would behave much like an computer-controlled highway, but would simplify some of the parking and vehicle management problems in dense areas. Instead of leaving the small car parked, it would be returned to the system for rental by another user (Ref. 64).

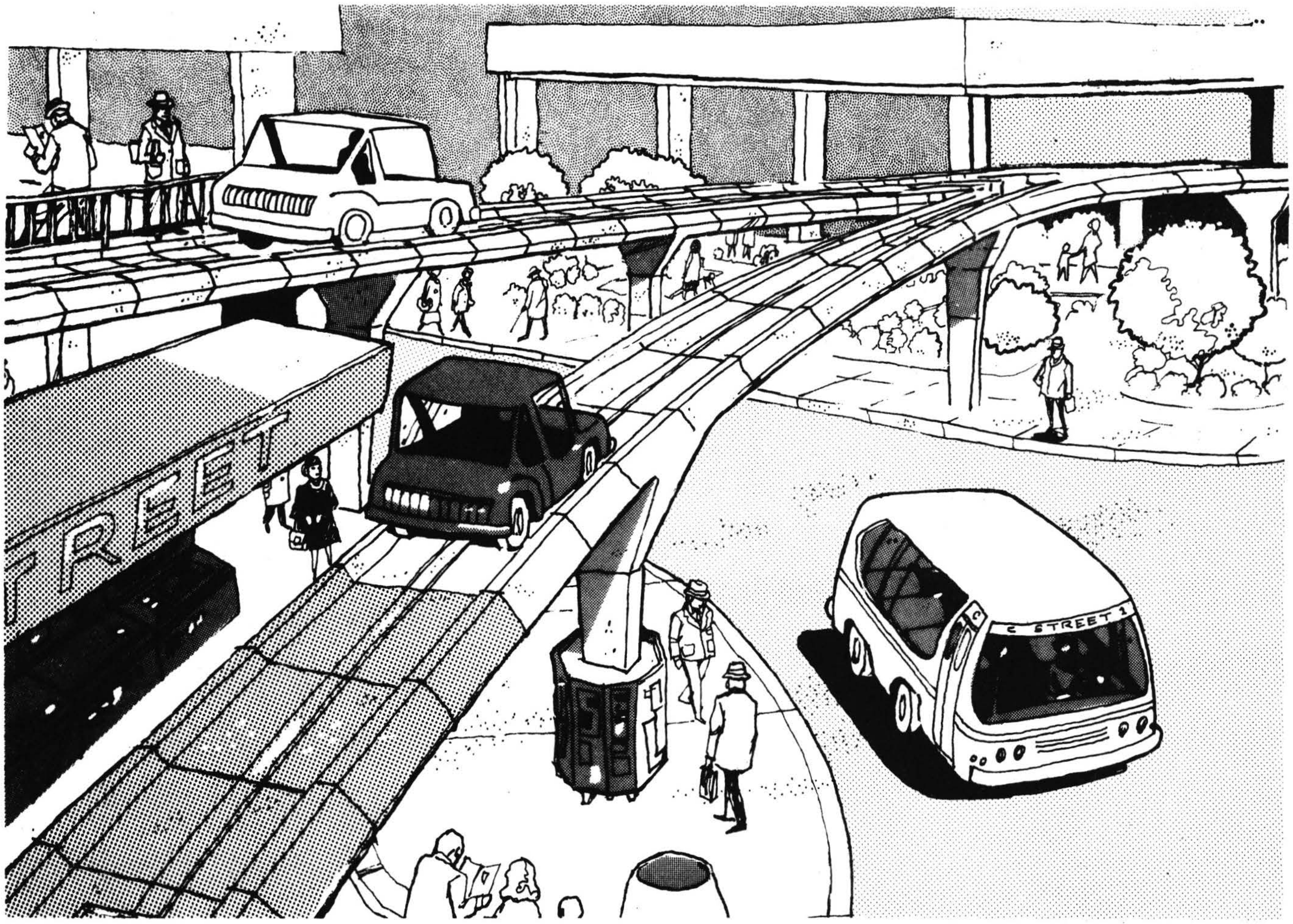

Figure 5. Dual mode systems might combine the flexibility of the passenger car with many of the benefits of transit.

Full-scale dual mode systems probably will not become operational before 1990 at the very earliest, and more likely will begin to proliferate after the year 2000. Concept studies and hardware tests are continuing.

G. Hovercraft.

Cities located on rivers or lakes may consider hovercraft -- typically, water-based vehicles which ride on an air cushion -- as options. The concept of using waterways for mass transportation is by no means novel. At the present time, hovercraft are used in more than 23 countries around the world for commuting and tourist purposes. Cities, faced with daily traffic congestion on land arterials and demands for more expensive highways and bridges, might find the idea of water-borne "express buses" a welcome alternative.

With the use of modern, high-speed vehicles, trip times on the water can compete favorable with auto trip times, particularly during peak periods. These craft can cruise at about three times the speed of an ordinary boat, and can offer more attractive economies over long distances. Also, it may be possible to serve areas which are not easily accessible by land transit. Demonstrations need to examine such areas as consumer acceptance, reliability, economics, user response to changing fares, and how to improve craft design (Ref. 73).

II. System Integration

Despite the spectrum of options available to meet urban transportation needs in the future, no current single option has the flexibility to perform well under the full range of demands and capacity requirements which characterize urban transportation. At least three types of trips have to be served:

1. Circulation traffic - the movement of large numbers of people relatively short distances (less than 1 mile), in and around major activity centers.

2. Line haul traffic - moving large numbers of people longer distances (5-10 miles), on a regional basis.

3. Collection/distribution traffic - moving people to access line haul modes, or getting them a short distance to their destination after a line haul trip.

With the possible exception of some dual-mode concepts, no system can serve all types of movement at all demand levels. Autos work very well at lower travel densities, but require too much space for movement and parking to be effective for circulation or collection/distribution at activity centers. Rapid rail and the other fixed guideway systems function well at high demand levels, but cost too much to install or operate as travel density drops (Ref. 69).

The result is a need for an urban transportation system which consists of a mixture of the options previously described, operating cooperatively with service tailored to the area being served. The issue is not necessarily one of diverting people from automobiles, but rather supplying a better public option for elements of the urban trip for which the car is unsuited. There are also issues associated with the transfers between elements of the system, and assuring the reliability of the various total system elements.

Multi-element bus and paratransit systems are already operating in cities like Rochester, New York and Ann Arbor, Michigan. Future systems will probably tie in fixed guideway modes to serve high density corridors, as well as people movers for dense areas. Such a strategy can provide coverage of entire urban areas. There is analytical evidence that in medium-size cities, where the ratio of suburban area to downtown is not too great, the money lost in low-density suburban and feeder operations can be made up for by profits from more heavily travelled routes; that is, internal cross-subsidy would make a total system economically feasible (Ref. 55).

Figure 6. Rochester, New York provides transit service to some of its suburbs with these vehicles.

Since the mid-1970's, Federal programs have been emphasizing the concept of transportation system management (TSM). Under this concept, transportation planners try to make the best use of existing facilities by encouraging carpooling and vanpooling, priority services for buses and carpools, and facilitating use of transit wherever possible. A wide variety of operating, service and regulatory changes can be used to accomplish this.

The success of a TSM strategy depends on packaging various mutually supportive transportation policies and actions to compliment each other. For example, a bus and carpool priority lane can be installed in a heavily travelled corridor. This "busway" can then be supported by constructing fringe parking lots, improving local arterials, promoting carpool matching and transit services, and other policies favoring transit. Carpooling provides an especially high-payoff approach to making good use of existing highway capacity.

Figure 7. Knoxville, Tennessee uses a minicomputer, accessed by this terminal, in its carpool matching and brokerage operations.

A notably effective measure to encourage carpooling and transit usage is establishing a formal brokerage program. Such an arrangement helps form carpools by finding potential riders, may assist in the purchase of vans for pooling purposes, and helps potential transit riders get schedule information. A particularly innovative operation is currently running in Knoxville, Tennessee, which uses a minicomputer for carpool matching and transit information. The City of Knoxville and the Transportation Center at the University of Tennessee received an UMTA Administrator's Award in 1977 for implementing the brokerage concept.

Chapter 3: Small City and Rural Transportation

I. Introduction

The passenger transportation problems of rural areas in the United States revolve primarily around the transportation disadvantaged --those young, old, poor, handicapped or unemployed residents who either do not have access to cars or who cannot make full use of the cars they own. As such, rural and small city transportation systems are heavily involved with social service aspects of providing accessibility. This section will discuss the developing scope of this problem in the U.S., and explore how some "urban" options have been adapted to deal with the problem.

II. Dimensions of the Problem

From 1920 to 1970, the United States rural population essentially remained constant. However, the total U.S. population doubled, with almost all of this growth occurring in urban areas. As values changed, younger people and the more affluent residents left rural society and migrated to urban regions. In effect, the low-density areas were being left to the aging and the poor (Ref. 44).

Fully forty percent of America's population currently lives in rural areas. However, since 1970, basic reversals of the rural outmigration pattern have taken place, and rural areas are growing again. Although this speaks well for the long-term viability of such areas, the set of problems associated with having large numbers of poor and elderly will remain with them for some time to come.

As with most portions of the country, the private automobile has been the dominant source of rural mobility in recent years. In 1973, some 80 percent of rural households in the United States owned at least one automobile. However, if the car breaks down, or costs rise too high to operate it frequently, or the driver lacks the physical ability to safely control a car, the owner of the vehicle is effectively stranded. Although others may be able to drive cars for them or they can "hitch" a ride with neighbors on a paid or unpaid basis, typically these approaches are of limited effectiveness.

Im most places, public transportation systems do not fill the gap associated with not having a car available. Air or water transportation are not widely available in low density areas, and conventional taxi service is prohibitively expensive. Intercity bus and rail systems have limited coverage. A secondary impact from loss of mobility also results: residents are unable to get to health care and other essential services. The need is to provide an alternative option for mobility in low density areas, which lessens the dependency on the private auto (Ref. 60).

There are basic policy questions as to whether the public sector must meet the noted need. Some say the public does not have to provide public transportation to rural society. They assert that if transportation is too costly, the individual could move to an urban community located near health centers, or make other arrangements. Others feel that society should make provisions to support the needs of these people as part of broadly based strategies to assure community viability. Ultimately, these questions have to be resolved based on local conditions and attitudes.

III. Local System Options

The problem of serving rural areas with transit is similar to that of serving the suburban areas of large cities, but complicated by the very low densities involved and the physical disabilities of many of the system users. Rural systems have to be able to operate economically in very thinly populated areas, and tailor their services to the requirements and limitations of each individual user. Paratransit variants and ride-sharing schemes therefore seem to offer the most promise of meeting rural needs:

Fixed-route minibuses can run on defined routes once or twice a week. Riders can board at widely separated stops, or arrangements may be developed to "wave down" the bus along its route. The latter approach is used by the Links system near Greenfield, Massachusetts.

Demand-responsive buses can be adapted for low-density service by requiring that users request service further in advance (1-2 days lead) than in suburban operations. This enables "tours" to be developed for the vehicles manually, without requiring sophisticated computer equipment. Use of radio dispatching allows demand-responsive service on a shorter turnaround basis, such as that provided by the Progress for People Human Resource Agency in Tennessee (Ref. 36).

Existing urban systems can be extended into surrounding rural areas on a limited basis. For example, the Honolulu, Hawaii city transit system extended its coverage to provide mobility to some of the more rural areas of the Island of Oahu. However, the economics of such an approach need to be examined closely before a decision is made to proceed.

Ride-Sharing Systems can be developed to pool available transportation resources. This can include forming bus or van pools where the vehicles are owned by a public agency or a major employer, or by subsidizing owners of existing vans. For example, Knoxville, Tennessee has developed an evolved commuter vanpool system which reaches far into surrounding areas.

School buses in off-duty hours can provide public transportation. There are some regulatory barriers to this approach, and the narrow aisles and small seats on the bus may be a problem for some mobility-limited people. However, the buses represent a resource already in place, and some demonstrations, including one UMTA sponsored temporary operation in Klamath Falls, Oregon, indicate potential for the approach.

Figure 8. The Area Transportation Authority of North Central Pennsylvania serves citizens in six rural counties of the state.

Because of the cost of running such services, some people also have proposed mechanisms to directly provide cars to rural residents. One example was the West Virginia Community Action Agency, which provided cars to individuals, then made these people responsible for transporting other users in the community. Proponents claim this approach is cheaper in the long term than providing transit. Full-scale rural systems may use any or all of these approaches in some degree (Ref. 60).

IV. The Subsidy Issue

Because of the extremely low densities involved, it is relatively certain that rural systems will not pay for themselves out of the farebox, and it is probable that a high level of subsidy will be required. Since many of the services provide elderly or handicapped residents access to social service programs, such programs frequently have transportation components which can pick up part of the costs. It, therefore, appears that service coordination is the key to viability of future rural systems: serving the requirements of the clients of a number of social service programs, and picking up some support from each.

The service coordination approach to funding and operating a rural system is typically complex, for each Federal social service grant program in the United States has its own specific client group, eligibility requirements, bookkeeping and documentation standards, and local fund matching requirements. In systems which have made the approach work, one fairly dynamic person usually takes charge and makes the various pieces fit together. As a result, management training for system operators may be one of the most important ways to insure that future rural transportation needs are addressed.

During the summer of 1978, a number of key officials from the U.S. Department of Transportation (DOT), other Federal agencies and staff of the U.S. Congress visited a number of rural and small urban systems. The problems of state and local governments in providing this type of service were reviewed, and recommendations for improvement were voiced. This information is being used to develop guidelines for the administration of a new DOT rural and small urban transit assistance program, and to develop a joint policy with the U.S. Department of Health, Education and Welfare on social service transportation coordination (Ref. 57).

Chapter 4: The Private Automobile

I. Introduction

The private automobile's degree of impact on the life style of people worldwide would have been practically unthinkable at the time the first "horseless carriages" were introduced. Many cities around the world were maturing as the auto came on the scene, and the spatial structure of many of these urban centers was predicated on having the auto or any auto-like system for mobility. This section will examine the role of the private automobile, and speculate on its technological future.

II. Dominance of Transportation

The dominant element of passenger transportation in the future will probably be a descendent of today's private automobile, and for good reason. The car provides a combination of personal service and schedule flexibility at an "acceptable" cost no other mode can match. The key reasons for this dominance include relatively low cost, high reliability, instant accessibility, fast travel time and ability to haul packages.

A comparison with other methods of getting to work may be instructive. A 4-person carpool using sub-compact vehicles for a 40-mile round trip will cost each carpool member about $.60 per day, assuming current petroleum prices and that the employer provides parking spaces. A comparable bus round trip will cost at least $1 and frequently more than $2. Under current operational concepts, the bus trip could take twice as long, may require a change of vehicle, will often require standing, and may necessitate a walk in the rain or snow.

The private car is currently used for some 90 percent of all passenger transportation in the United States. Even assuming a major energy shortage forced people to select common carrier modes for a large number of their trips, the dominance of the automobile would probably continue. For example, even if ridership on all other common carrier modes doubled, the automobile would still account for some 80 percent of all trips (Ref. 2).

In many cases, the automobile is the only option which can reasonably be used. The coverage of the highway net in technologically evolved countries means that the private car can reach some places which no other mode of transportation can. Some types of low density air service could be considered as an alternative, but the costs would be prohibitive. This is especially important in light of the rural and small city development trends noted earlier. Only for long distance trips has the auto been challenged by the common carrier air services for patronage.

Some basic psychological reasons have also been proposed for this dominance of the private auto. The driver of a car has a great deal of power under his or her control, and is in effect master of his/her own destiny for the duration of the trip. This personal autonomy may serve a balancing role against many of the depersonalizing, dehumanizing trends in a large highly organized society. The car has also evolved into a basic role as a status symbol in many societies. Common carrier modes may attempt to replicate the car's service characteristics and improve their amenities, but they will find it hard to match these subtler roles the car plays in our modern culture.

III. Limits on Applicability

Unfortunately, the popularity of the private automobile has created some adverse side effects which limit its applicability for some transportation roles. The auto requires a great deal of space for operation, storage, and parking. These characteristics make it unattractive as a mode of transportation in central cities.

When people bring cars into the city or other activity centers on work or shopping trips, there are few problems at the low-density end of the trip. However, as traffic builds up, the various arterials congest, more parking space is needed, and more support facilities have to be installed. There may be "better," or at least more profitable, uses of available land in urban centers than for parking. Eventually no more space is available, with the result that some downtown areas have more or less continuous congestion all day. The car helped create this urban growth pattern and is helping to perpetuate it, since low-density suburban residential areas still have to be served.

The automobile has also been a major contributor to air pollution problems in large cities. Regulatory approaches on a city-wide level have to date been unworkable in the United States, simply because no really acceptable transportation alternative to the car exists for the general public. Just as autos dominate transportation in general, they dominate urban transportation also. Doubling or tripling the availability of public transit, even if it was possible to attain an acceptable level of ridership, would have a limited impact on total automobile usage. It would require major investments in new transit facilities, and would probably just slow the growth of auto traffic in urban areas.

The automobile at present is the largest single consumer of petroleum, using about 50% of the petroleum consumed for transportation in 1975. Since the late 1950's it has been necessary for the United States to import oil from a wide variety of foreign sources, and in the mid-1970's over one-third of the petroleum used in the U.S. was imported. From a national policy standpoint, major dependence on foreign oil is undesirable. The potential for interruption of supply and the outflow of money (dollars) from the U.S. (or any) economy has negative impacts. In addition, competition for existing petroleum resources will increase in the latter part of this century, resulting at least in higher prices for the available supply.

The net result is that some changes will be necessary in the ways automobiles are designed and operated. There are technological approaches to reducing automotive energy consumption and pollution. As cars get smaller, the auto's excessive space consumption will diminish somewhat and might be further helped by public policies encouraging a shift to more space efficient modes.

IV. The Design Problem

Traditionally, the consumer has been able to choose from a wide variety of car types and models. Sizes ranged from small "subcompacts" to full-size "luxury cars," with their size and correlative status. However, the impacts of these design choices have forced examination of whether their benefits were justified in light of their broader societal costs. A Federal Interagency Study of Motor Vehicle Goals (MVG) beyond 1980 singled out several areas of impact of the passenger car:

1. Total Fuel Use
2. Deaths and Injuries
3. Air Quality and Health
4. National Resource Availability
5. Automotive Industry Impacts
6. Consumer Costs
7. Broader Impacts on the National Economy (Ref. 74)

Figure 9. This Research Safety Vehicle was built under contract to DOT's National Highway Traffic Safety Administration.

These general areas are interrelated, since a decision to improve automotive performance in one area may lead to undesirable changes in the other aspects of performance. Auto designers now recognize the environment the car will be operating in, and make tradeoffs between the various elements and features of the car to bring its impact into line. The Motor Vehicle Goals study selected automotive fuel economy as a major goal in the design process, and assessed its impacts on other attributes:

1. Size (Roominess)
2. Performance (Acceleration and Gradeability)
3. Auto-Structure Technology
4. Engine Technology
5. Drivetrain Technology
6. Emission Control Technology
7. Emission Standards
8. Safety Requirements

Examples of the types of vehicles which result from making these tradeoffs can be found in the National Highway Traffic Safety Administration's Research Safety Vehicle (RSV) program. The RSV program focuses on developing and testing cars which weigh less than 3000 pounds, achieve fuel economy in excess of 30 mpg, and provide occupant protection in a 40 mph head-on collision. The Calspan Corporation of Buffalo, New York and Minicars, Inc. of Goleta, California were selected to build prototype RSV's. The Calspan vehicle design involves integrating current design advances for an operative weight of 2700 lbs. The Minicars vehicle design uses lightweight materials and structural innovations in its approach, resulting in an automobile weighting 2320 lbs.

Features under test in the RSV prototypes include a reinforced structure, run-flat-tires, electronic instrument displays, foam-filled body structure members, damage-resisting bodies, anti-skid brakes and radar actuated brakes. The Minicars vehicle should have a fuel economy of some 34 miles per gallon with a stratified charge engine. By integrating advanced technology engines and transmissions with lightweight vehicles, fuel economy levels of 50 to 60 miles per gallon appear feasible in the longer term (Ref. 42).

V. Engine Technology and Fuel Economy

One approach to improved fuel economy is the use of automotive powerplants other than the Otto cycle spark ignition engine currently used. In the near term, the diesel engine looks promising, having a considerable fuel economy advantage over conventional powerplants. The emissions of hydrocarbons and carbon monoxide from diesel engines are naturally low, and devices such as catylytic converters are not necessary to meet pollution standards. However, the diesel's emissions of nitrogen oxides are a problem and must be reduced. The engine also emits other pollutants including particulates and sulfur oxides. Recent data, however, has indicated that these pollution problems may be soluble.

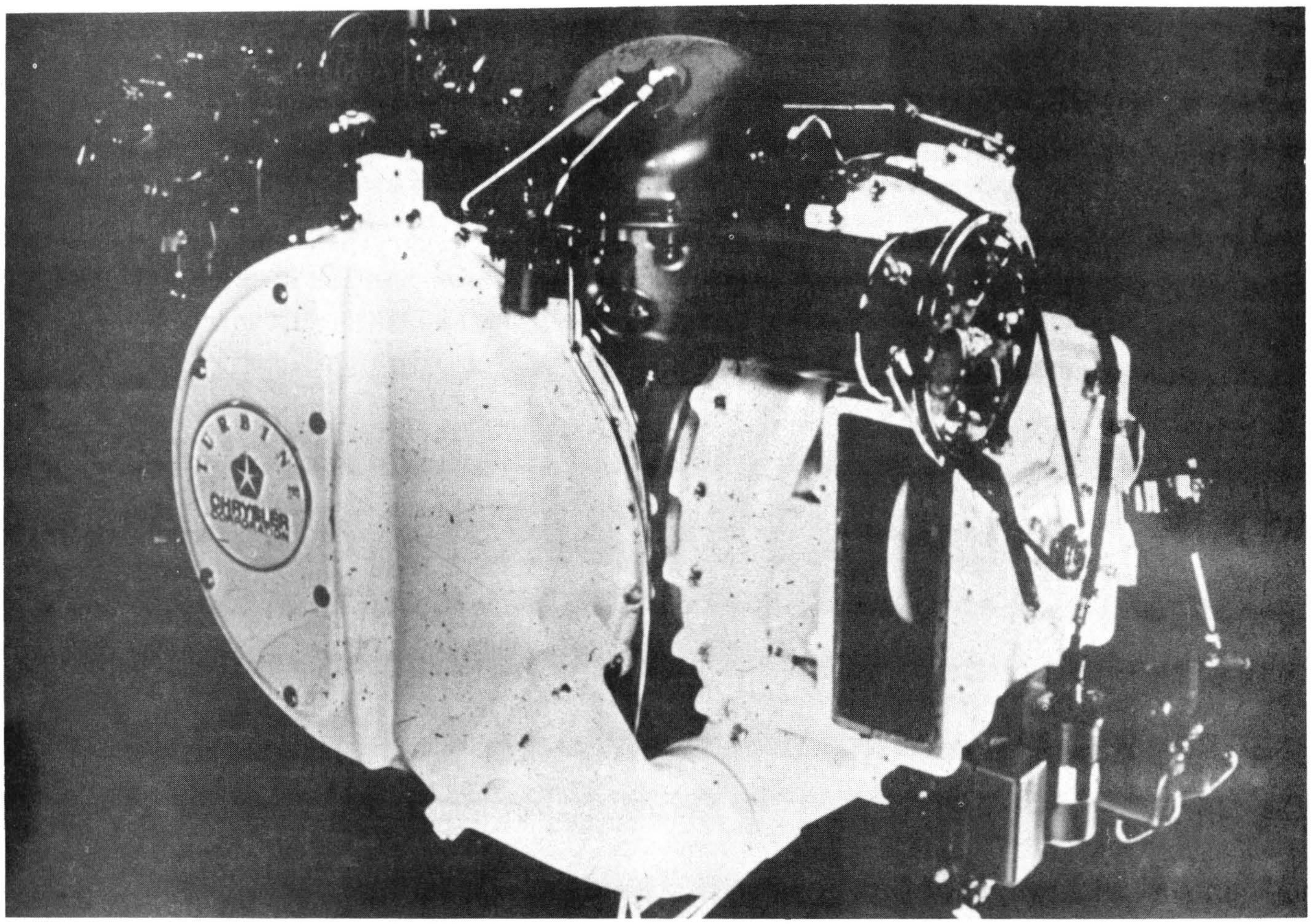

Figure 10. Automobile gas turbines could run on a variety of fuels.

In the longer term, other advanced technology engines show promise. Engines based on Stirling (expansion and compression of sealed working fluid) or Brayton (gas turbine) power cycles might meet both the U.S. emission control standards and 27.5 mile per gallon fuel economy standards. However, it is unlikely that any vehicles using these powerplants could be in production before the late 1980's (Ref. 74).

Another long-term possibility is the electric car. Benefits of such vehicles include reduced petroleum consumption and the virtual elimination of air pollution from the car itself. Any major application of these vehicles is contingent on breakthroughs in battery technology. Otherwise, future electric cars will be very small vehicles with short range and poor performance. A number of advanced battery research projects are underway. Such an approach does allow the substitution of power sources discussed earlier (Ref. 74). Some electric vehicles, designed for special purposes and limited use, may be on the road by the mid-1980's.

Advanced research is also being applied to another candidate for on-board storage of energy -- flywheels. Computer simulation indicates that a very significant fuel economy could be achieved by using a flywheel spun by a small diesel engine running constantly at its most efficient speed, and accelerated by electric energy derived from generators used to provide braking force in the deceleration cycle. Several other configurations of flywheel energy storage systems are under study. Encouraging results are emerging from research intended to increase the energy density (storage capacity) of flywheels. The regenerative feature of flywheels renders them particularly suitable for propelling vehicles which make frequent stops.

In the very long term, hydrogen may be considered as an automotive fuel. It is not expected to be practical until after the year 2000, since there are many production, storage and handling problems to overcome.

VI. Safety

Both technological and behaviorial approaches to the problem of highway safety are possible. Changes in the highway system and auto vehicles to achieve safety have been numerous, as shown by the following examples: (1) The Interstate Highway System is estimated to save 8,000 lives annually when it is complete in the mid-1980's. It is currently estimated to be saving about 5,000 lives each year. (2) Use of lap belts and shoulder harnesses have already saved thousands of lives each year, even with partial usage. (3) Improved highway design and technology over the years has made substantial contributions to highway safety including flatter grades and curves, longer speed change lanes, anti-skid surfaces, paved shoulders, and increased sight distance. (4) Judicious use of traffic control designs has included better centerlines, delineation posts, direction and other signs, flashing beacons, curve warning signs, wider lanes, and stabilized shoulders. (5) Improved design of car interiors has included padding, recessed steering wheels, breakaway knobs, and head restraints. (6) Vehicle technology contributing to safety included automatic transmissions, power brakes, tires, vehicle lighting systems, and power steering. Taken together, all of the foregoing have, over the last six decades, resulted in a substantial fatality reduction.

Although some additional technological approaches to the problems of highway safety are possible, many of the measures having the greatest potential benefits seem to be those focused on creating behavorial changes in auto drivers. The U.S. 55 mph speed limit appears to have had a major impact on reduction in the number of auto accidents and the deaths and injuries resulting from them. Based on the Motor Vehicle Goal Study noted earlier, the single action with the most potential to improve highway safety would be to make seat belt usage mandatory. Such a law reasonably could be expected to cause 70 percent of passenger car occupants in the United States to wear their safety belts.

The current estimate is that the 9,300 fewer lives would be lost each year if this noted level of belt usage was obtained. This estimate is somewhat higher than previous estimates (8,500) because they were based on observed belt usage in traffic being 20 percent at that time. However, a recent survey shows in-traffic belt usage is now 15 percent and, accordingly, the original estimate of the life-saving potential of belt laws was increased to reflect this difference.

Approximately 20 countries have adopted laws requiring the use of safety belts. In those countries where there has been sufficient public information and enforcement, these laws have been quite successful in reducing motor vehicle fatalities and injuries. Nevertheless, the fact that no State in the U.S. has yet adopted such a law--despite a number of attempts to do so in several States--indicates that the political practicality of such an approach in this country is questionable at this time.

A more practical alternative to achieve auto lifesaving goals is to protect vehicle occupants with automatic or "passive" restraint systems. These passive restraint systems require no action to "buckle-up" as a precondition for protection in a frontal crash. Beginning in model year 1982, the Federal safety standards for motor vehicles will require full-size cars sold in the U.S. to be equipped with passive restraints. Midsize cars and small cars will have to be equipped with passive restraints in model years 1983 and 1984, respectively.

Two types of passive restraints which satisfy the standard have emerged from safety research programs. These are the air bag and the automatic seat belt. The "airbag" is probably the most widely known of this family of automobile safety packages. The system uses an inflatable bag contained in the dashboard or steering wheel of a vehicle, and an inflating cartridge connected to a sensor system. When the sensors, typically located in the front bumper or instrument panel, detect a deceleration typical of an accident situation, they trigger inflation of the bags, thereby cushioning the occupant from severe impact with the vehicle interior.

Another type of passive restraint is the automatic seat belt. Developed by Volkswagen, it is in use on Deluxe Volkswagen Rabbits. The "belt," which is actually a shoulder harness, automatically moves into place as a person boards the vehicle and shuts the door. Relatively slack at most times, the harness locks in a crash situation, "gives" a little to absorb crash energy, and then locks again before the passengers contact the front vehicle structure.

There are also automotive safety problems associated with drinking drivers. Strict enforcement of traffic laws and associated public information programs to increase perception of the likelihood of being apprehended if one drives after drinking may be the most effective long-term way of controlling this problem. Improved technology has also had some beneficial impacts in this area. Notable advances include use of video tapes of intoxicated drivers as evidence to get convictions, chemical breath testers, and automotive ignition interlocks which require more physical coordination to turn off than a drunk driver has. In addition, potentially beneficial effects may be obtained from other devices now in the development cycle, such as a "drunk-driver warning system," designed to reduce the incidence of drunk driving by individuals previously convicted of driving while intoxicated.

VII. Impact of Electronics

Use of sensors and electronics have already made great impacts on traffic control. Automated systems can detect changes in flow rates on major roads and alter signal timing patterns to keep traffic moving smoothly. Motorist information systems, which display data on developing jams or alternative routings on variable message signs or transmit it by radio, are also entering wider use. The proliferation of citizen's band (CB) radio also serves this function to some degree, and there have even been discussions of requiring CBs in future cars.

Computer applications to other modes have been much more visible but there also seems to be some potential for their use in private autos. The development of microprocessors is one technical breakthrough which makes possible computer application in cars on a scale which would have been impractical with conventional computer technology. In particular, the interactive road vehicle system described earlier for urban applications may also evolve on an intercity basis. Automated highways have been discussed for years, but technical advances now seem to make the concept more economically feasible (Ref. 56).

There are also attempts ongoing to make existing navigation systems more applicable to a wide variety of users. For example, the U.S. Coast Guard operates LORAN (Long Range Naviation) - C, a radio navigation system, which has been used at sea. Several land-based applications of the system are now being investigated, including automatic monitoring of police or transit vehicle positions, highway accident location, automatic vehicle location or dispatch, and highway inventories. Major productivity improvements associated with the application of the technology appear probable.

Chapter 5: Intercity Passenger Transportation

I. Introduction

With some indications that national population shifts are occurring, intercity passenger travel may assume an added importance. Traditionally, the private automobile and common carrier aircraft have divided the intercity travel market, with the car taking most short trips and air taking a good proportion of the longer ones. In particular, air travel accounts for over half the person trips over 1000 miles in length. This section will discuss some of the possible future prospects for air and the other intercity transportation modes.

II. Intercity Bus Systems

Because of the coverage of the national highway network, intercity bus sytems have the potential to extend service to a wide variety of locations. Typical bus speeds, terminal to terminal, have been similar to the automobile, assuming non-stop service. In markets where travel demand cannot economically justify non-stop service, operators must augment their routes with intermediate stops to supplement their ridership and revenues. If these stops involve extensive wait, or are any substantial distance from the main route, they can degrade travel time extensively. The costs of providing bus service are generally below those for air or rail trips, especially for shorter distances. It should also be noted that the bus has a major image problem -- bus service is considered "lower class" or "inferior," and bus stations do not have a good reputation for security (Ref. 34).

The intercity bus should remain an important mode in serving low-density areas like small towns or rural areas. As with any multiple-occupancy mode, there is some potential for energy conservation by shifting passengers from the private automobile, although a major shift would be required.

In corridor applications, there have been some concepts explored which would run buses at 90-100 miles per hour on exclusive lanes either on existing highways or with new construction. However, there have been no moves as yet to deploy such a system.

III. Passenger Rail Systems

Because of the high cost of their fixed facilities, passenger rail systems look attractive only where large volumes of people have to be moved in a corridor with limited space available for transportation. This is one reason, along with regulatory and similar obstacles, for the poor economic performance of rail systems on low density routes.

There is also a basic incompatibility between passenger rail systems and those of conventional rail cargo operations. Rail freight trains generally travel more slowly and put more demands on trackage (pounding, heavy loading) than do passenger trains. This means that if passenger and freight trains share the same track the passenger service will be degraded by the slower, heavier freight trains which the express passenger trains encounter along the route. Suggestions have been made that future passenger and rail operations may need to have separate guideways, each dedicated to its own particular type of service. Such an approach would involve major investment in new trackage or upgrading of existing lines.

Some idea of the costs involved in upgrading lines for high-speed corridor service may be gained from the United States Northeast Corridor Improvement Project (NECIP), focusing on the 456-mile route from Boston to Washington. The Railroad Revitalization and Regulatory Reform Act of 1976 originally established a $1.75 billion upgrading program. This program's goal involves reducing trip times in the corridor to three hours and forty minutes between Boston and New York, and two hours and forty minutes between New York and Washington. These schedules are to be reliable, and include intermediate stops.

In January 1978, the Secretary of Transportation asked for an evaluation of the existing program and called for a realistic plan for completing the NECIP, taking into consideration the needs of all corridor users, intercity rail, commuter, and freight. This Redirection Study showed that additional time and an increased authorization from Congress would be necessary. The recommended program will cost $2.5 billion. This figure represents the original $1.75 billion, a new authorization of $654 million, and includes $66 million of public grade crossing funds and $30 million of non-NECIP funds for Union Station. The revised program is scheduled for completion in 1983.

Another approach to achieving high speed rail service is by upgrading vehicles to run at higher speeds on existing track. This approach is taken by the English Advanced Passenger Train (APT). The APT vehicle has a specially designed suspension system which compensates for track irregularities, and its cars "bank" to take tight curves.

Rail systems may become especially important if major oil shortages occur and it becomes necessary to shift corridor travel from cars or planes to other options. Since rail systems can be run electically, can be powered by coal-based synthetic fuels (or even can use coal-fired steam, if it really became necessary), they may become the dominant mode of corridor travel for medium-distance intercity trips in a tight energy scenario (Ref. 58). In the interim, the economics of rail systems are a serious concern on a national scale.

IV. Tracked Levitated Vehicles (TLV)

Tracked Levitated Vehicles (TLV's) is a general term which refers to high-speed ground systems with non-contact suspension, usually

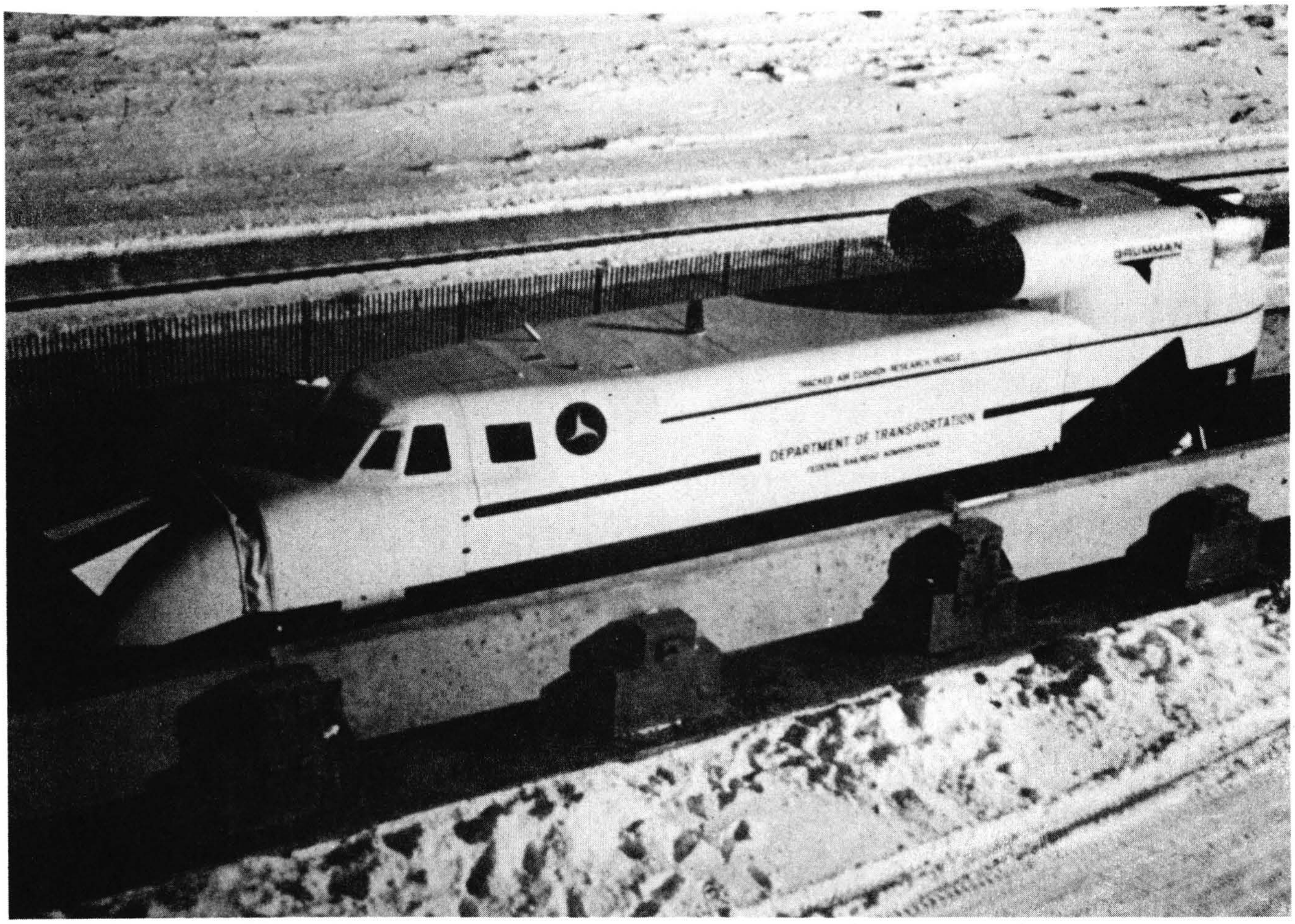

Figure 11. This Tracked Levitated Research Vehicle (TLRV) was tested at the Department's Transportation Test Center near Pueblo, Colorado.

operating in the 150-300 mile per hour speed range. These systems operate on fixed guideways like trains, but instead of having wheels they are levitated so that they do not physically touch the guideway itself.

Levitation may be provided by an air cushion or by use of magnetic forces. Magnetic levitation (MAGLEV) may be based either on repulsion of like magnetic poles to hold a vehicle off a guideway, or attraction of unlike poles to lift it off the ground and towards a supporting rail.

Propulsion for these high speed systems would probably be by a linear induction motor, powered with electricity picked up from a collector near the guideway. Turbo-jet propulsion might also be a possibility, but noise and other environmental factors make this unlikely.

The TLV's are a longer term option for the corridor markets served by high speed rail. Because of the high per-mile cost of their guideways and the need for large-radius curves when turns are made, the installation costs of these systems are fairly high. One 1974 analysis, probably conservative by now, placed their fixed facility costs at $7.0 million per mile outside urban areas. A good part of the urban costs of TLV systems are associated with tunneling, so a technology breakthrough in that area might improve their attractiveness somewhat (Ref. 76).

Because of costs, potential environmental impacts, and political feasibility, TLV systems are currently looked on with serious questions in some quarters. However, current projections by the Office of the Secretary of Transportation indicate that, even with the Northeast Corridor upgrading program, the transportation system in the Boston-Washington corridor will probably reach capacity by 2010. If a major diversion to rail from auto or air occurs, this date may advance. The TLV technologies are one option for providing the additional capacity needed in this and similar applications (Ref. 52).)

Research on TLV technologies is continuing in Germany and Japan. In one especially notable project, Japan Air Lines has funded development of a 190 mph attraction-type MAGLEV test vehicle. This vehicle is the first step towards a projected transport system between the Tokyo New International Airport and downtown Tokyo. If funded, the 40-mile distance would be covered by an operational system in only 14 minutes (Ref. 17).

V. Air Systems

As mentioned previously, air transportation dominates longer-distance trips, and is the most popular common carrier mode for trips over 200 miles. Barring any major petroleum shortage, this dominance should continue, especially because of the speeds and high level of amenity which characterize air travel. There are a number of paths of technical improvement which might be followed:

1. Advanced technology subsonics - The next generation of commercial jets is expected to incorporate several new technologies to cut operating costs and reduce energy consumption (Ref. 35). One design approach might be to use mildly swept-back, high aspect ratio (long, slender) wings and control surfaces, possibly incorporating supercritical wing profiles and active controls. Small aerodynamic improvements such as winglets may also be employed. Winglets act in the crossflow on the main wings, producing a net forward thrust and saving some 4-6 percent on fuel (Ref. 11). Composite materials, consisting of graphite or boron fibers embedded in an epoxy matrix, may be used to cut structural weight. Composites have already been used in helicopter rotor blades and in making secondary structures in commercial transports.

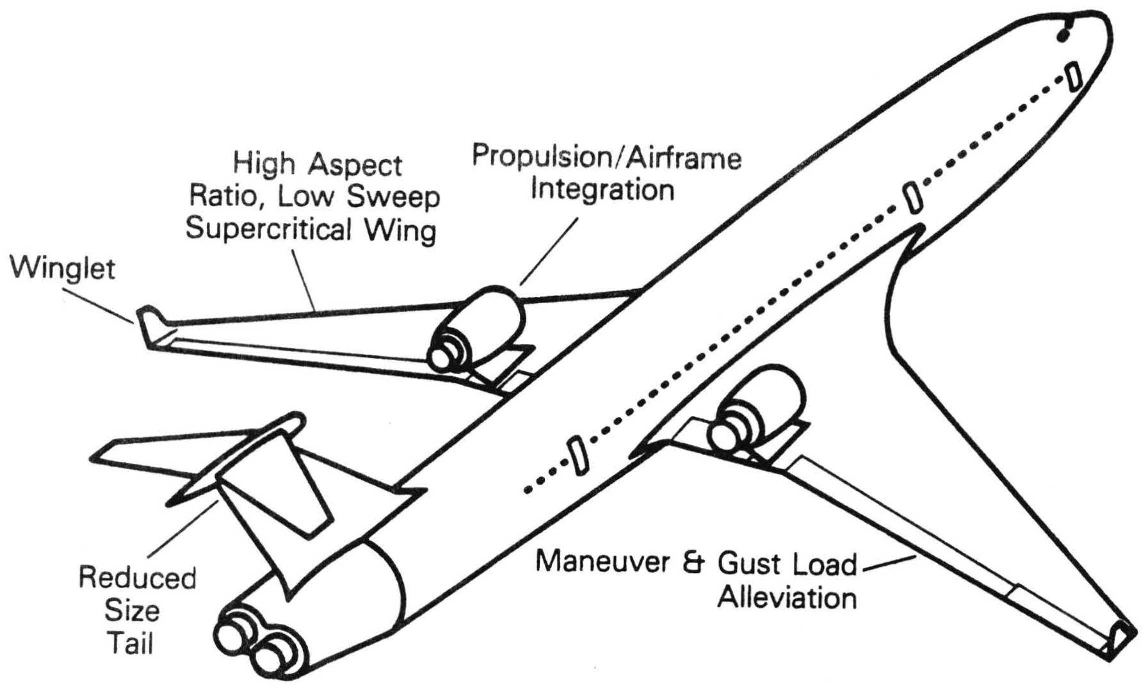

Figure 12. This diagram illustrates some features considered for advanced subsonic air transports (adapted from Ref. 35).

Improved propulsion technology can also provide some modest significant efficiency gains in the next generation of engines (Ref. 35). Advanced technology turbofan engines could increase fuel efficiency at least 12 percent (Ref. 24) by a combination of component improvements, such as exhaust stream mixing, better clearance control at the tips of compressor and turbine rotors, low-loss seals, and refined blade shapes in fans, compressors and turbines. Other gains will result from improved engine diagnostics and design for lower performance degradation during service life.

The first of this new generation of new jetliners should enter service in the early 1980's. Planes under development include Boeing's 757, 767, and 777; an improved McDonnell Douglas DC-10; Lockheed's L1011-400; and the Airbus A300-200.

Later introduction of advanced turboprop engines will potentially reduce fuel consumption by an additional 15 percent (relative to the improved turbofan). The key in turboprop technology is the achievement of high efficiency at the speed at which turbofan transports fly while also maintaining the same satisfactory levels of noise and vibration inside the passenger cabin.

Technological improvements in both turboprop and turbofan engines should continue to reduce the area around airports which is affected by aircraft noise especially during landings and takeoff.

2. Short and reduced takeoff and landing aircraft - By using an airplane's propulsion system to augment its wing lift, adding special flaps, or making other design changes it is possible to cut the length of runway needed for an aircraft to take off or land. This capability also reduces the airspace required in terminal operations.

   Propulsive lift techniques for achieving this include internally blown flaps powered by air bled from engine turbines, externally blown flaps using engine exhaust, upper surface blowing using engine exhaust, augmentor wings using entrained air, and vectored engine thrust. Unfortunately, these changes require higher relative initial investment costs, and also increase operating costs and fuel consumption. In addition, environmental pressures and safety considerations militate against the siting of new small airports downtown or in densely populated areas (Ref. 11).

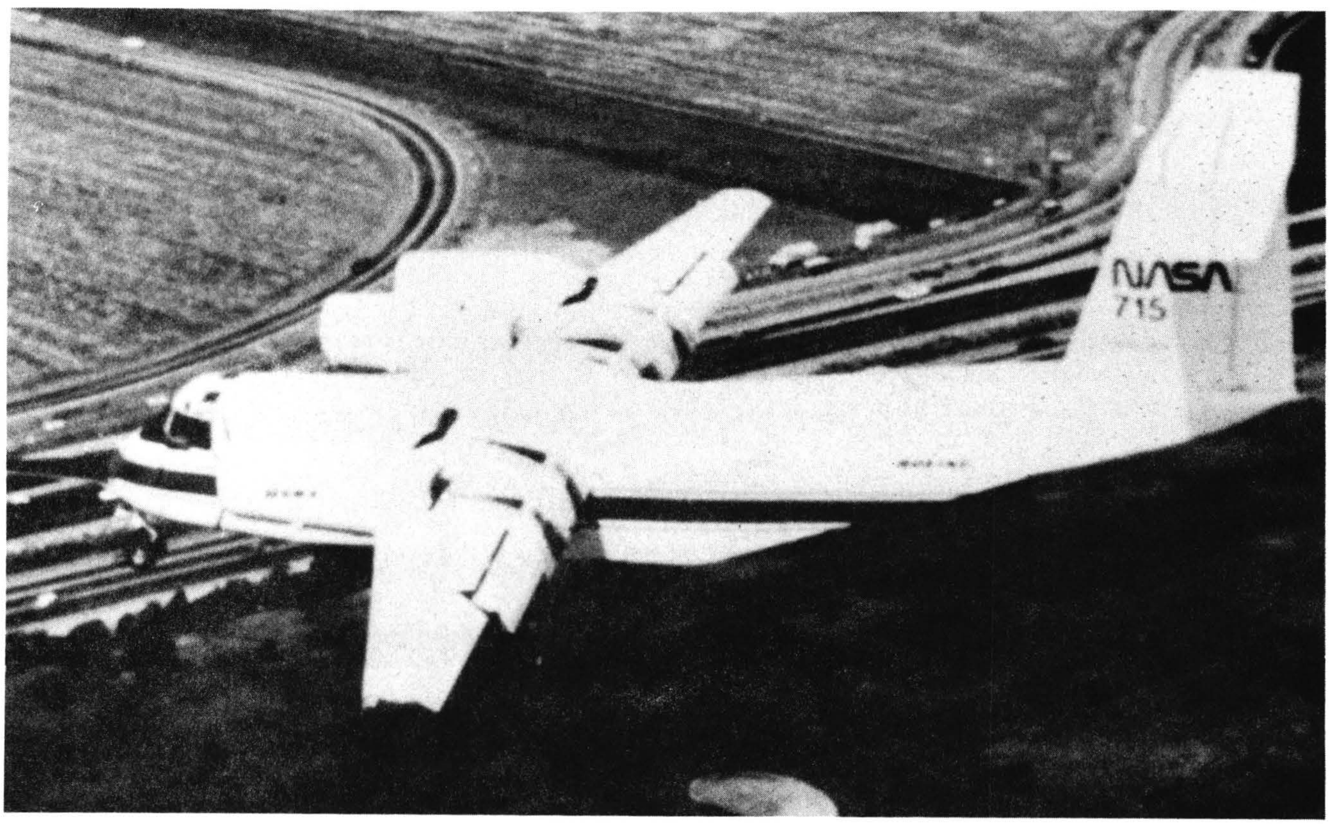

Figure 13. NASA's Quiet Short-Haul Research Aircraft (QSRA) is shown approaching its landing strip. (Picture courtesy National Aeronautics and Space Administration).

It is therefore unlikely that short takeoff and landing (STOL) aircraft operating from runways under 2500 feet will enter extensive commercial use in the near future. However, short runway aircraft (SRA) systems, using 3500 to 5000 feet runways may become commonplace, especially if capacity increases and constraints on the availability of new large airports force major use of smaller, existing satellite airports (Ref. 32).

3. Vertical takeoff aircraft and helicopter variants - Vertical takeoff and landing (VTOL) capability is even more costly than STOL, but offers a potential point-to-point feature which may compensate. As with STOLs, use in downtown areas is unlikely, unless there is a change in many of the current popular attitudes about environmental impacts and safety. However, there have been many breakthroughs with respect to helicopter costs during the 1960's, and helicopter variant or hybrid systems exhibit some promise in the longer term. Depending on the course of development, these systems may be useful for airport feeder service or trips in the 100-300 mile range; those which today are "too far to drive and too short to fly" (Ref. 56).

4. Supersonic aircraft - Today's Concorde aircraft have operating costs which are triple, and total costs which are double, those of wide-body subsonic aircraft on a seat-mile basis. Their fuel usage is three times as high as a subsonic aircraft. Using the aircraft technology of the late 1970's, a second generation SST could be built whose direct costs would be considerably less than double, and total costs 40 to 50 percent higher than a Boeing 747.

   This, of course, assumes that technology to improve subsonic performance of the aircraft has been implemented in order to minimize overland range penalties, since sonic boom restrictions do not permit supersonic domestic operations. FAR-36 (heavy weight) noise certification of these planes would be required and achievable. EPA terminal area emissions standards would have to be met, and nitric oxide emissions at cruise would have to be low enough to assure that no serious damage is done to the upper atmosphere's ozone layer.

5. Hypersonic aircraft - There also may be the possibility in the longer term of hydrogen-fueled hypersonic transports, flying at 5-6 times the speed of sound at altitudes above 100,000 feet. Technologically, the craft requires major advances in propulsion, structures, and aerodynamics. At present, the supersonic combustion ramjet, or scramjet, is the only known air-breathing engine which can operate above Mach 5 (five times the speed of sound). This engine would have to be perfected to make the concept feasible.

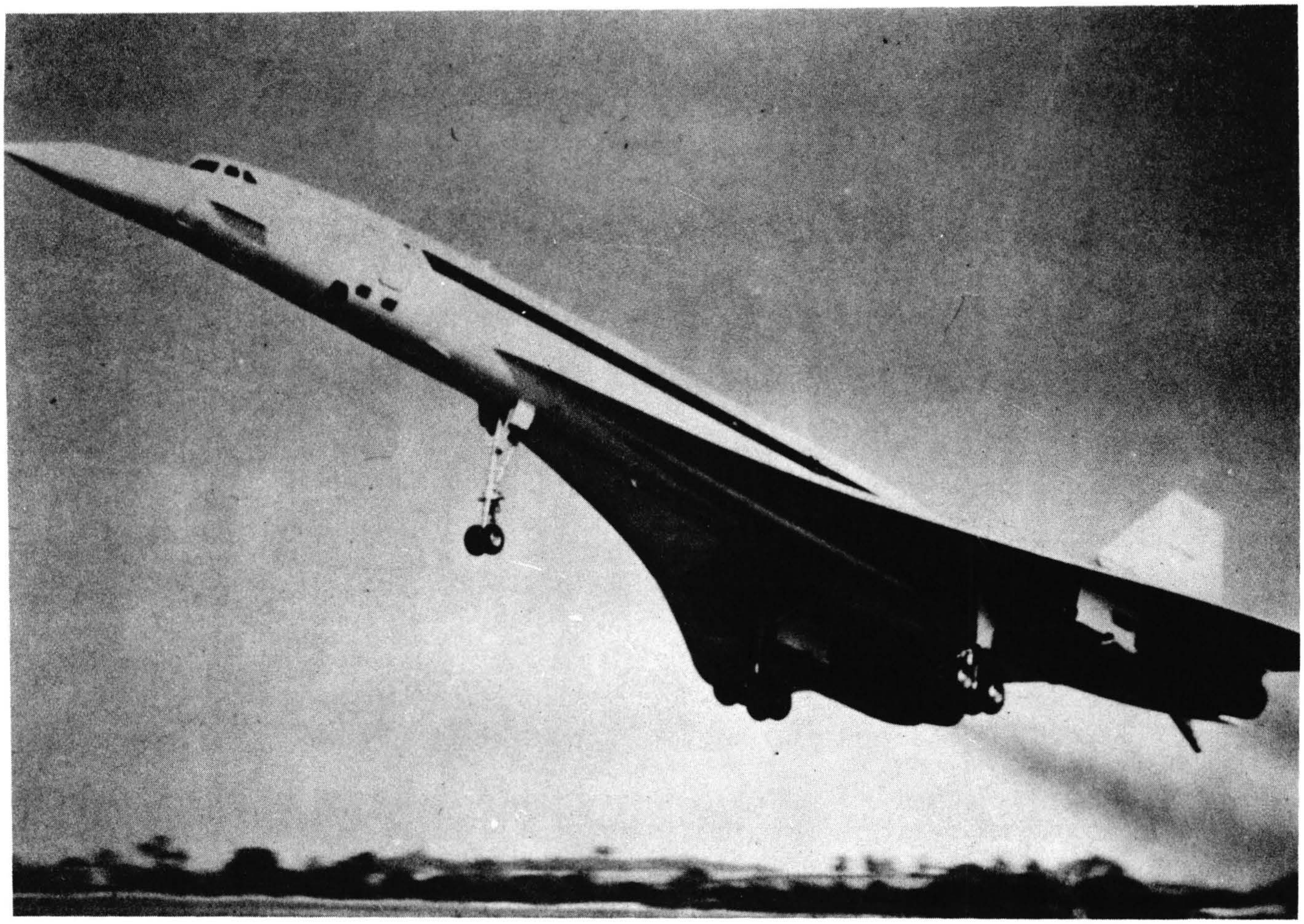

Figure 14. The Concorde was one of the first operational passenger SST's.

The costs of developing either an SST or an HST aircraft would be enormous, and the development investment may be beyond the capability of any one manufacturer. Some type of government assistance is, therefore, probably needed. It may be in any number of forms, including enabling legislation to waive antitrust restrictions, loan guarantees, or risk limitation. Direct government support of a prototype aircraft is not an agreed upon element in an SST or HST development program (Ref. 20).

6. Lighter Than Air (LTA) Craft - Studies (e.g. Ref. 19) have identified new uses for lighter-than-air vehicles. The principal one is heavy vertical lift for use in short haul operations such as ship-to-shore cargo hauling, logging, power line construction, remote area resource development, and high rise construction (Ref. 4). Another application would be in passenger transport from outlying areas to regional transportation centers. A third use would be in low speed, long endurance patrol missions.

These airships would not resemble past dirigibles. They would be hybrids combining helicopter-type propulsion and control and buoyant hulls. A number of organizations and countries have expressed interest in developing such vehicles. Some proposals (Ref. 30) have been made for extremely large airships for long-haul transportation of passengers or cargo, but economic studies have not revealed a significant market potential (Ref. 32).

To assess which of these future developments in aviation were most likely, and under what circumstances they would most probably occur, DOT's Federal Aviation Administration undertook a study of alternative aviation futures. The results, summarized in the report Aviation Futures to the Year 2000, set out five broad scenarios ranging from limited to expansive growth of the air system and projected the most likely system characteristics for each. The study's findings include the following (Ref. 47):

1. With moderate to high economic growth, new conventional aircraft like a 150 passenger jet STOL or a 1000 passenger jumbo jet transport might be in service by the end of the century. Unconventional aircraft in air carrier applications are unlikely.

2. Extensive use of semi-automated and automated air traffic control systems will probably be necessary.

3. Major additions to airport capacity, including some new air carrier airports and a substantial number of general aviation airports, will be essential.

4. Use of non-petroleum fuels is unlikely, but more fuel-efficient transports should be available.

5. Aircraft noise will continue to be a constraint on system growth.

Eventually, petroleum shortages may force consideration of new types of fuel. Synthetic jet propellants might be made from coal. Other fuels which might be used include liquid hydrogen or methane. (Ref. 10) The United States once had a nuclear aircraft developmental program but it was shut down in the early 1960's because of problems in meeting military requirements and achieving a lightweight, well-shielded reactor system. A civil aircraft with nuclear power would also have problems with environmental constraints and economic requirements. However, fuel shortages, combined with technical advances, may one day lead to reconsideration of this option.

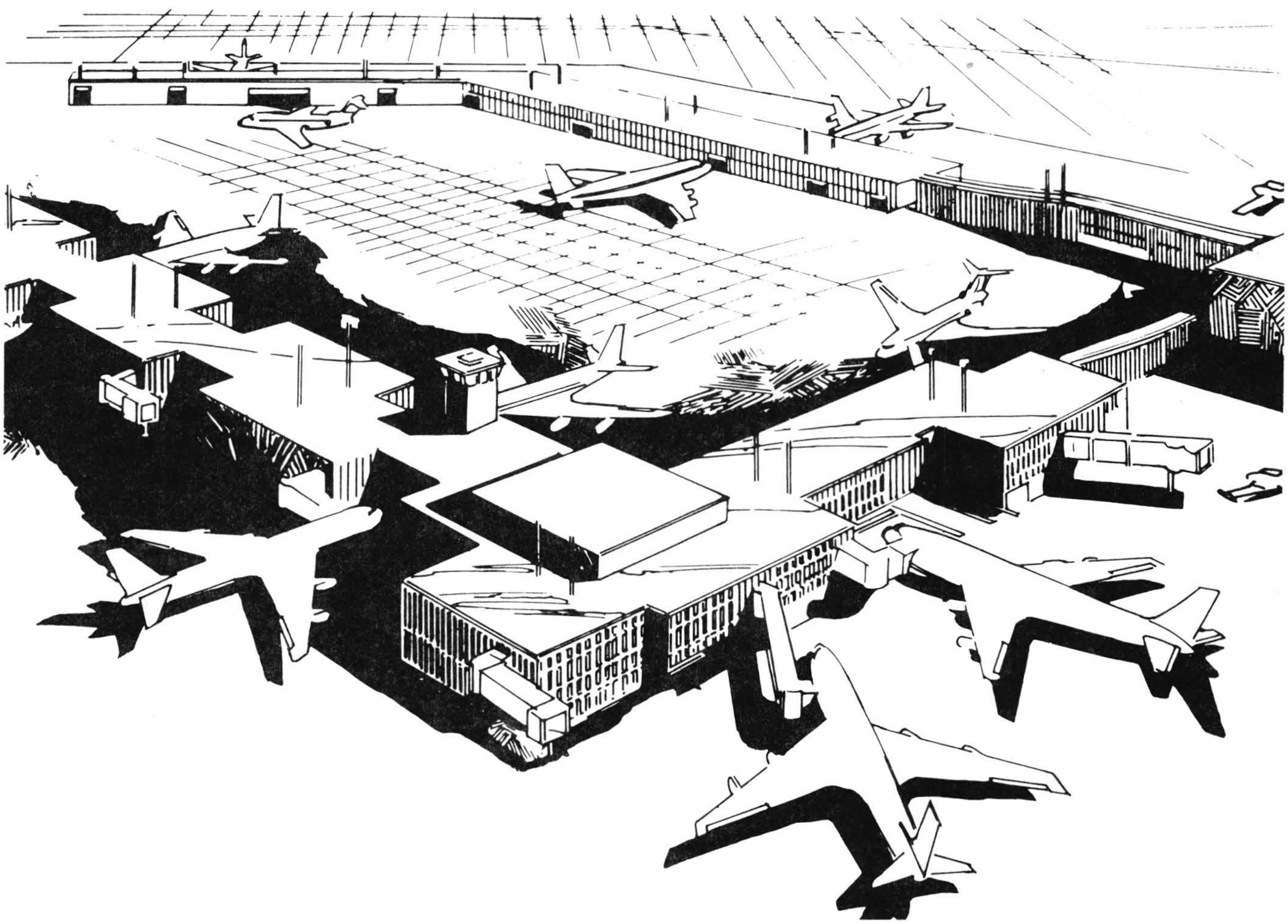

Figure 15. Growth in air traffic levels also requires development of ground facilities to match these demands.

It should also be noted that, whatever the vehicle technology, growth in air traffic levels will probably continue. A fuel shortage could constrain this growth for a time, but there is the option of developing a new generation of alternative fuel powered aircraft as the shortage developed. Under any scenario, increases in capacity levels will necessitate major improvements in the national air traffic control system, with extensive use of automation to increase individual controller productivity and assure safety. Within the terminal areas themselves, improvements in passenger processing, baggage handling, and intra-airport transit capacity will be necessary to increase landside capacity. As traffic levels grow at some hubs, satellite or reliever airports located at some distance may become necessary.

Traffic increases also require a concerted effort to control aircraft noise and reduce adverse environmental effects. As noted before, work is continuing on air transport noise reduction, which should ameliorate that problem somewhat. However, as new quieter transport aircraft are introduced, pressures may develop to remove older, noisier aircraft from service. Solutions discussed range from retrofit or noise treatment of engines on older aircraft all the way to removing the older planes from service entirely.

VI. Marine Systems

Passenger marine transportation has declined until recently, with much of the long-range traffic diverted to passenger airliners. However, there are some applications where new marine systems may show promise for medium distance shuttle or ferry runs. For example, hydrofoils have been successful transportation sytems on a global basis. It is estimated that there are at least 900 of these craft operating in the East Bloc alone, and successful hydrofoil technology is now decades old.

Another type of craft is the wing-in-ground effect vehicle. Such craft are being investigated in the Soviet Union and West Germany, both in large and small sizes. Flying close to the ocean surface, these craft would operate in a high lift to drag regime. Some configurations can operate out of ground effect as conventional aircraft with some loss in efficiency and speed. They are potentially highly flexible, efficient vehicles.

Surface effect ships, which amount to large ocean-going hovercraft, are another possibility. In very large sizes, these vessels become highly efficient, and are excellent candidates for nuclear or hydrogen propulsion.

There may also continue to be advances in conventional passenger ships. Nuclear powered ships may be one possibility, but they are proposed more frequently for cargo than passenger applications. The three nuclear-powered commercial ships built by the mid 1970's--the United States' NS Savannah, the West German NS Otto Hahn, and the Japanese NS Mutsa--have all been cargo vehicles (Ref. 23).

It should be stated that many of the technical advancements in maritime transportation originate outside the United States. This is particularly so in the advanced vehicle areas, where the U.S. tends to concentrate on a few very large devices.

Chapter 6: Cargo Transportation

I. Introduction

This section will discuss the possible future of freight transportation, and the impact which new technology may have upon it. In some respect, cargo transportation problems are more complicated than those of passenger transportation, since people are relatively homogeneous in size and shape, and can assist in making their own routing decisions. The spectrum of commodities and items shipped by freight is broad, including small packages and shipments of highly valued items like electronic components, perishables like fruits and vegetables, heavy manufactures like farm equipment, and bulk commodities like grain, oil, and coal. Each of these types of items has to be treated differently. A remarkably diverse and complex freight system has evolved worldwide.

II. Trucks

In the United States, intercity trucking has carried some one-fifth of all intercity freight transported, measured on a ton-mile basis. Some projections to 1990 actually show trucks surpassing railroads in total freight carried. To handle the diverse commodities shipped by truck, a wide variety of special sizes and configuration vehicles has been developed. To a considerable degree the combination of special components can be specified by prospective buyers. Trucks are typically classified by gross vehicle weight, and only the two heaviest classes (class VII, 26,001-33,000 lb. and class VIII, above 33,000 lb.) are really significant in intercity freight.

Because larger trucks may be operated at lower costs per ton-mile to the operator, and may consume less fuel on a relative ton-mile basis, there have been some recommendations that size and weight restrictions placed on larger trucks be modified to allow use of the more efficient sizes. Later, double 40-foot trailers may be allowed on some controlled access roads, but triple trailers will probably remain limited to the handful of states that presently allow them.

It should be noted that the splash and spray effects of large commercial vehicles, especially at speeds over 50 mph, can be annoying, and perhaps even hazardous, to motorists sharing the roads with larger vehicles. This may be especially important as passenger cars shrink in size in connection with the push for improved fuel economy. The safety performance of the larger vehicles themselves is being examined, and DOT's Federal Highway Administration expects to have findings from a six-state accident study available in 1979. There have also been questions raised about increased requirements for maintenance of roads with extensive heavy truck usage.

There are a number of improvements which can be made to the truck itself. Available technology engine improvements can reduce a truck's fuel consumption by seven percent. Use of a fan clutch could produce a six percent reduction. Placing an airshield or deflector on the top of a tractor-trailer's cab to smooth airflow over the trailer triggers a four percent reduction in fuel used. Even a simple action like switching to radial tires improves large truck fuel economy some six percent (Ref. 8). (These economy improvements are not additive.)

In the longer term, truck-train systems, either on reserved highway lanes or special separated roadways, might evolve. This possibility is especially probable if competing railway service continues to decline, and intercity trucks have to begin carrying more bulk commodity shipments (Ref. 67).

It is likely that trucks will maintain their major role in small package delivery and urban goods movement. If auto congestion continues in downtown areas, pressures may develop to confine truck loading and unloading activities in population centers to night hours.

In addition, trucks have developed reputations as major sources of noise and pollution on urban highways. Truck noise levels are now subject to Federal standards for new and in-service vehicles, and tire noise is soon to be similarly regulated. In addition, significant reductions in truck noise have already been realized. Research on alternative methods of quieting trucks continues, as does examination of the emissions problem.

III. Railroads

Railroads are currently the number one mode for movement of intercity freight traffic in the United States on a ton-mile basis. There is a network of some 200,000 miles of rail in place in the U.S. railroads, which moved some 37 percent of the domestic ton-miles shipped in 1975. However, rail's market share of the intercity freight market has steadily been declining. The advantages once held by rail in moving bulk commodities have been eroded by pipeline and barge traffic. Trucks have also made inroads into the rail markets, aided by the Interstate Highway System and service flexibility.

Many of the problems of the rail industry in the U.S. have been attributed to complexities of regulation and taxation. However, two major problems of rail operations have been poor service, in terms of both shipment time and reliability, and poor productivity of existing equipment. Trains spend an extensive amount of time having their various cars separated and reassembled into new trains in intermediate yards. This repeated process of taking the cars of the train apart and putting them back together into new trains with different destinations not only contributes to a long delivery time but also compromises the reliability of service (Ref. 70).

Figure 16. Trailer-on-Flat-Car (TOFC) services have been in operation for some time and could take on added importance in the future.

One solution to the yarding problem might be to schedule more and shorter trains, operating at higher frequencies and requiring fewer intermediate stops. This approach would imply an increased use of automation, although not necessarily a reduction in personnel, since more trains would require crews.

Increased use of containerization has been occurring, and may accelerate in the future. This could involve trailer-on-flat-car (TOFC) services with trucks, or container-on-frame-car (COFC) services with a variety of modes. Terminals for such trains might consist of large automated warehouses, rather than the marshalling yards which are current today. Depending on the evolution of the passenger rail system, these new trains might operate on existing or upgraded rail trackage specifically set aside for the purpose, on new guideways constructed in existing rights of way, or may continue to share the rails with passenger services (Ref. 56).

IV. Air Carriers

Domestic air cargo carries less than one percent of all freight movement, but is a rapidly growing industry. Air generally provides the lowest door-to-door transit time for shipment distances over 600 miles. However, direct truck service is generally quicker than air for distances under 500 miles and remains somewhat competitive for shipment distances up to 800 miles. Compared to truck shipments, air is relatively high-cost, and has typically been used for shipment of relatively small, high-value packages with a time premium. For longer distances, especially international, air is used for a wider range of commodities.

A number of options are currently used for the shipping of freight by air. Narrow-bodied freighters are used in three major applications: charter flights, scheduled operations of all-cargo carriers, and combination passenger-cargo carriers. Wide body passenger jets carry cargo in their lower holds, and some wide body jet freighters have entered service (Ref. 70).

With the same trends pushing for an increase in airliner size operatng for freight as well as passenger planes, the trend towards jumbo jets should continue. Very large aircraft, with payload weights up to a million pounds, may develop. These large freighters should be equipped to handle intermodal containers as well as the current types of freight.

Realization of the potential of air cargo to provide unique service characteristics, such as schedule reliability and special handling as well as speed, depends heavily on solution of ground interface problems. Problems of ground access, terminals, custom clearance, paper work and containers must be given attention.

The possibility of using lighter-than-air (LTA) craft as heavy lift freighters has also been discussed. The most promising concept is one combining buoyancy and rotors for propulsion and control. Its use would be for very short haul cargo transfer or precision vertical lift of heavy or outside items. These vehicles also may be useful for military and law enforcement applications particularly if maneuverability requirements are emphasized in the design. Long-haul freight transportation by LTA appears to be uneconomical.

V. Marine Options

Maritime transportation will maintain a continued importance in freight movement. The United States grew largely because of its rivers and canals, and its ports located on its rivers, Great Lakes, Gulf Coasts and sea coasts. Its domestic commerce is maintained, in large measure, by its river steamers, barges, and Great Lakes grain and ore carriers; its foreign commerce maintained almost entirely by its freighters and tankers.

There is heavy domestic freight movement on inland and intercoastal United States waterways. Most of this traffic is carried in towed or pushed barges, although a limited amount of cargo is carried in shallow-draft inland freighters. These services are especially useful for low-cost movement of bulk commodities where speed is not important. Speeds of barge traffic are typically slow, some 5-6 miles per hour, although some high speed tows can go as fast as 15 mph.

The great potential improvements for these services will probably come from better integration of deep-draft (ocean) and shallow-draft (inland) shipping. Containerization has potential for integrating these services, and LASH (lighter-aboard-ship) system and Seabee barges show even more promise. Under these concepts, oceangoing freighters can take loaded inland waterway barges aboard and transport the entire assembly. The barges can access the oceangoing services from fairly long distances, and be used for distribution once the seagoing freighter reaches its goal (Ref. 54).

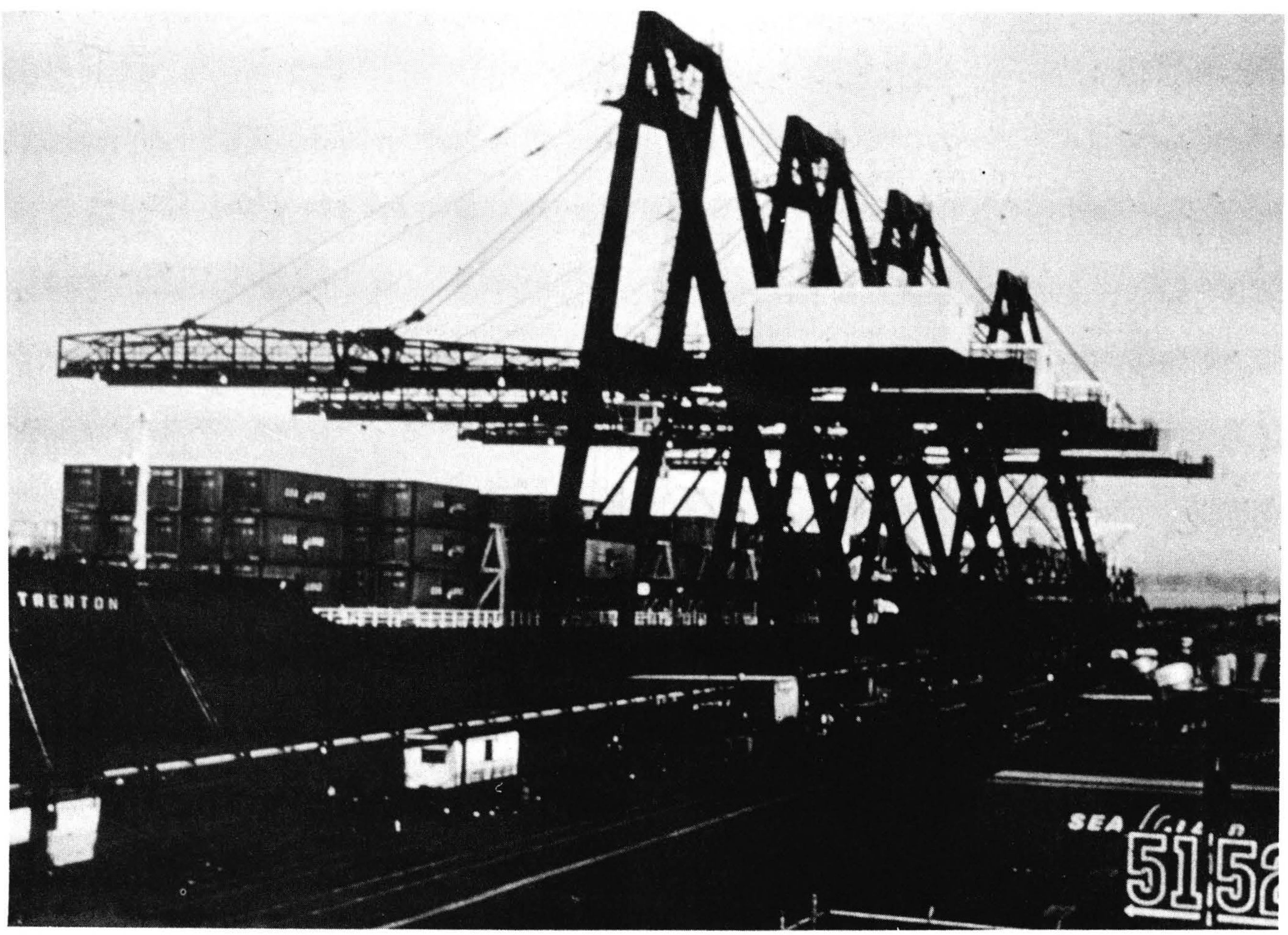

Figure 17. Large container ships should continue to be a mainstay of tomorrow's maritime cargo transportation system.

The trends towards making oceangoing ships larger are continuing, and even larger tankers and container ships are likely to develop. There likewise is continuing pressure to develop deepwater ports and other specialized facilities needed to serve these larger ships. Intermodalism is probable, both with standardized containers, and with LASH and Seabee.

Some of these new super-freighters and tankers may be nuclear-powered. However, for nuclear power to be competitive with conventional powerplants, it must be used in ships with a need for high power levels, and which receive heavy utilization. Studies of nuclear ships therefore, focus on large, fast containerships, with capacity utilization of over 70 percent (Ref. 23).

Wind Augmented Vessels, the descendents of sailing ships, may prove economically viable once again as the cost of fossil fuels increase. New sail forms, new materials, satellite weather information, and computerized operating systems could make such vessels effective, efficient elements of the national transportation network.

Hydrofoils or large oceangoing hovercraft may also see some cargo application, but there have been few U.S. efforts to develop them at this writing.

VI. Pipelines

The pipeline mode will probably continue to evolve, maintaining its important role in the delivery of liquid and gaseous products. The Alaska oil and gas pipelines are illustrations of the opportunities and problems this approach presents. Slurry pipelines, where powdered solids are mixed with a liquid, then pumped through the pipes and the liquid extracted at the destination, are also a possibility. However, this approach requires a plentiful supply of liquid (usually water) at the origin of the pipeline.

Another emerging technology which may see application is the pneumatic capsule pipeline. Under this approach, shipments are placed in closed standard containers and propelled through a large pipeline by air pressure. Small-scale systems of this type have been in use for years, and some pilot or test systems have also been built using the larger-scale technology.

Chapter 7: Space Transportation

I. Introduction

The area of spacecraft evolution has been one of the fastest developing areas in all transportation. It was only twelve years from the orbiting of the first earth satellite to the first manned landing on the moon. Between the direct impacts of satellites and other orbital systems (for example, intercontinental television, remote sensing, and improved weather forecasting), and the indirect impacts of technologies developed for the space program (for example, microcircuitry, advanced insulation, and new plastics and synthetic material), life styles worldwide have been profoundly altered. Improvements in navigation for air and marine systems have already resulted from use of satellite systems, and further improvements are probable. This section will discuss some ongoing programs for spacecraft development, and note some of their longer term implications.

II. The Space Shuttle

The Space Transportation System, or space shuttle as it is more familiarly called, is being designed as the world's first manned reusable spacecraft. Each craft is designed to be orbited some 100 times and to be capable of carrying a 65,000 lb. payload into a 240-mile high due-east orbit. Each flight will cost some $10.5 million, amounting to a cost of some $160 per pound to orbit a payload. This is a substantial savings over conventional boosters, which cost some $500-1000 per pound to orbit their payloads (All costs 1974-75 dollars, from Ref. 75).

The shuttle consists of four major elements. The heart of the system is the orbiter, a rocket plane about the size of a DC-9 which can be flown into, and back from, earth orbit. During takeoff, the orbiter rides upon a 27-foot diameter, 155-foot long tank which carries much of its fuel. The fuel used for these flights is liquid hydrogen with a liquid oxygen oxidizer. The tank is the only part of the vehicle which is not recoverable. To provide additional needed thrust during liftoff, two solid propellant boosters of 2 1/2 million pounds thrust each straddle the fuel tank. Total weight of the vehicle at takeoff is some 83 tons.

The orbiter's structure is primarily aluminum. It relies on a different heat protection approach than the ablative materials (which melt, carrying away heat) most re-entry vehicles have used. In particular, the nose and wind leading edges of the vehicle are covered with carbon caps. Silica tiles are used to protect the rest of the vehicle.

The large size and flexibility of the orbiter provide a number of advantages conventional launch vehicles have not had. It can not only carry payloads to and from orbit, but also has the capability for in-orbit operations. The orbiter's payload bay is some 60 feet long and some 15 feet in diameter. As a result, many of the weight and volume constraints imposed on previous spacecraft payloads could be relaxed somewhat. Since the orbiter is manned, this allows the vehicle

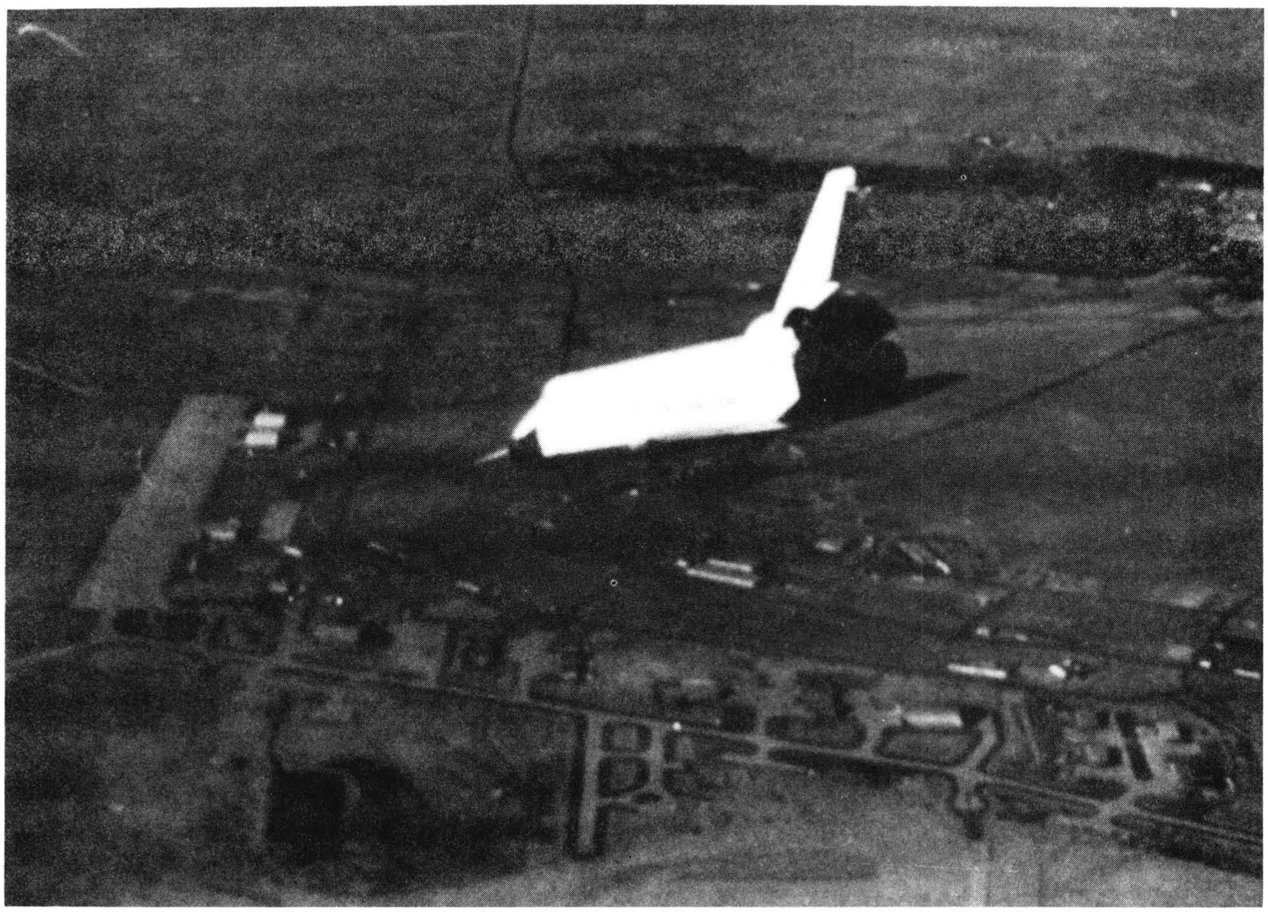

Figure 18. The space shuttle has been designed as the first re-usable manned spacecraft. (Picture courtesy National Aeronautics and Space Administration).

to rendezvous with satellites already in orbit and repair or refurbish them. If necessary, satellites can even be retrieved by the orbiter and returned to earth for reuse or repair. Considerable cost savings may result from such reuse (Ref. 3).

To place payloads into higher orbits, the packages can be equipped with "tugs," or propulsion units. In this approach, the payload is lifted into low orbit, placed into space, and its engine triggered to place it on the desired trajectory.

The basic shuttle mission is limited to seven days in orbit. However, with extra provisions and a smaller payload, flights up to 30 days can be attempted with a standard shuttle configuration.

III. Future Orbital Systems

The space shuttle is the first step in the possible evolution of an advanced family of manned orbital systems. Several options are open, none of which rule out the others except on resource grounds. For example, one approach might be to upgrade the existing shuttle, substituting a new fly-back booster for the solid rocket engines. This new large booster vehicle could then serve as the basis for the development of a new, larger orbiter.

Another approach would be to push the development of a single stage to orbit (SSTO) shuttle vehicle. This vehicle, which would probably be hydrogen-fueled, could fly directly from ground into earth orbit, without requiring additional boosters. A number of launching options are open for such a vehicle, including vertical takeoff like the current shuttle, horizontal takeoff from a rocket sled or catapult, or some type of in-flight refueling before trying for orbit.

Once shuttle operations become commonplace, deployment of a long-duration orbital manned "space construction base" or "space station" might be possible. A construction-oriented space station could be operable by 1984. Assembled from modules carried up by two to four orbiter flights, it would allow continuous operations in low orbit by a crew of four to eight.

However, a more likely alternative involves using a "power and utilities module" to stretch orbiter missions. The module would provide solar-generated electric power and altitude control for the vehicle. It would be carried into orbit and deployed there by the vehicle. With the module connected to supply "plug in utilities," missions could be stretched to sixty or more days, after which food, water and other crew living factors become limited. Such a power module is now being explored, and a model supplying twenty-five kilowatts could be available in 1984.

While a twenty-five kilowatt power module will give the shuttle a substantial orbital capability, many other desirable applications require more power. These include advanced communications systems such as electronic mail, experimental evaluation of design requirements for a solar power satellite, materials processing and advanced space propulsion. NASA has, therefore, studied the possibility of a 250-kilowatt photovoltaic (solar cell) power module. Such a device, which has also been dubbed a "Shuttle Tended Space Platform", could be unmanned except when being serviced, or a "habitability" module could be added, allowing continuously manned operations. In either case, this would open the way to large-scale construction projects in orbit (Ref. 7).

In the longer term, especially if large construction projects are contemplated, there may be need for a heavy-lift (multimillion pound thrust) freighter. The various stages of this vehicle would have to be recoverable and reusable, but the payload might only have to reach orbit and not have a re-entry capability. This is especially true if it merely serves as packaging for a construction project being assembled by shuttle or advanced shuttle crews (Ref. 15). Extensive use may also be made of "free-flying teleoperators" (unmanned space tugs) to position and work with the materials once in orbit.

One major orbital construction project might be the deployment of a series of large solar collection satellites in geosychronous orbit (that is, one orbit takes one day at 22,300 miles, and the satellite appears to hover over one point). In this way the satellite would be illuminated and operative some 99 percent of the time. Collectors would have to be some 20 to 60 square miles in size to generate power of 5,000 to 10,000 megawatts. Electrical energy from the satellite would be beamed to earth by microwave using an antenna of 2000 to 3200 feet in diameter (Ref. 77). Availability of such cheap electricity would also have major implications for deployment of electrically powered ground systems.

In the longer term, full-scale colonies or manufacturing centers might be built in orbit. The major proponent of these concepts has been Gerard K. O'Neill of Princeton University. O'Neill describes orbiting manufacturing complexes in high orbits, staffed by work forces of 10,000 or more people, and provided with raw materials by magnetic catapults which would fire bulk commodities to there from the moon (Ref. 26).

IV. Deep-Space Systems

Manned craft should eventually follow the unmanned probes which have gone out to the planets and stars. A wide variety of technologies have been proposed for these missions, some of which are fairly exotic. Because of the projected long travel times for these trips, nuclear power is frequently proposed as their energy source. Among the engines which have been proposed are ion rockets, which accelerate charged atoms to high velocity using an electrically charged grid. Photon drive, which would involve the generation of an ultra-bright beam of light and using its pressure to propel the ship, has also been discussed. A nuclear pulse drive which would detonate a series of small nuclear or thermo-nuclear blasts behind the ship and ride their shock waves, has been considered (Ref. 5). Even huge solar sailing ships, driven by light pressure on their thousands of square feet of "sail," have been examined.

Conclusion

This report has dealt with some of the technologies which probably will be prominent over the next three decades. However, the broader impacts of these technologies are just as important, if not more so. State and local officials, after all, are interested ultimately in the social and economic well being of their jurisdictions. As a result, many are concerned with transportation primarily as an instrumentality in achieving broader goals.

These broad societal impacts of technologies are difficult subjects to learn about. However, the time which is required to develop and perfect the longer term options described here also gives us time to develop the more sophisticated understanding needed. We are not restricted to what is known now, and have the option to evolve new approaches to the structuring of our society. This is a tremendous challenge, but the stakes are equally high: the viability of an entire way of life.

The decision-making climate in this country is going through some major changes, too. Barriers between the various levels of government are breaking down, and a respect for the problems and capabilities of the other levels is developing in each. The possibility of cooperative action to solve national problems has never been greater.

All of these writeups have been based on evolutionary developments from existing technologies. As was noted previously, a true breakthrough in any area could completely redirect the course of transportation futures. The key is, therefore, to watch the various options as they evolve, and reflect them intelligently in implementation plans, since some of the the final technology choices for new sytems may be decades in the future. Typically, man tends to be optimistic about his future, and there may be every reason in this case to think that this optimism is justified.

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