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HYBRID VEHICLE POTENTIAL ASSESSMENT

Volume 2: Mission Analysis

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MASTER

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Jet Propulsion Laboratory
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ELECTRIC AND HYBRID VEHICLE SYSTEM
RESEARCH AND DEVELOPMENT PROJECT
HYBRID VEHICLE POTENTIAL ASSESSMENT
VOLUME II. MISSION ANALYSIS

September 30, 1979

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PREFACE

In 1976, Congress passed the Electric and Hybrid Vehicle (EHV) Research, Development, and Demonstration Act of 1976, Public Law 94-413, later amended by Public Law 95-238. The Department of Energy is conducting an EHV development program in compliance with that Law. The EHV System Research and Development Project, one element of this Program, is being conducted by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology through an agreement with the National Aeronautics and Space Administration. This report presents the results of the investigations conducted under the Hybrid Vehicle Potential Assessment Task which is a part of the EHV Systems R&D Project.

Early results of this study were used as the technical basis for the Near Term Hybrid Vehicle Development Program now being carried out by the JPL Electric and Hybrid Vehicle System Research and Development Project.

This report is in ten volumes. Volume I contains an overview of the study and the major findings. Volumes II through X are of technical supplementary reports that describe the details of the study and present the most important data generated by the study elements.

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Volumes Comprising the Hybrid Vehicle Potential Assessment

Report No.	Subject	Author(s)
5030-345, Vol. I	Summary	F. T. Surber et al.
5030-345, Vol. II	Mission Analysis	F. T. Surber G. K. Deshpande
5030-345, Vol. III	Parallel Systems	S. P. DeGrey
5030-345, Vol. IV	Series Systems	Z. Popinski
5030-345, Vol. V	Flywheel Systems	S. G. Liddle
5030-345, Vol. VI	Cost Analysis	K. S. Hardy
5030-345, Vol. VII	Hybrid Vehicle Review	K. O. Leschly
5030-345, Vol. VIII	Scenario Generation	K. O. Leschly
5030-345, Vol. IX	Power Train Summary, Component Descriptions, HYVEC Vehicle Simulator	S. G. Liddle S. P. DeGrey
5030-345, Vol. X	Electric and Hybrid Vehicle Cost Handbook	R. C. Heft S. C. Heller

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1.0 INTRODUCTION

This report documents the methods used to define the seven vehicle missions used in the Hybrid Vehicle Potential Assessment.

1.1 Scope of Vehicle Mission Analysis

For the purposes of this study, a vehicle mission was characterized by the following descriptions:

- 1) Transportation functions to be performed (trip purposes),
- 2) Payloads to be carried (passenger and cargo capacity and average payload weight),
- 3) Travel pattern (frequency distribution of km per day on an annual basis),
- 4) Typical driving conditions (driving cycle),
- 5) Minimum performance requirements (top speed, cruise speed, acceleration, gradeability),
- 6) Baseline vehicle characteristics (coefficient of drag, frontal area, coefficient of rolling resistance, and basic body and chassis weight).

Such a full characterization of a vehicle mission allows the analyst to design and compare alternate vehicle propulsion systems which are equivalent in function, minimum performance capabilities, and non-propulsion technology.

The marketability of hybrid vehicles in relation to specific missions was not

directly addressed. It was assumed that if hybrid vehicles could adequately perform the mission and were life-cycle-cost competitive that they were "marketable"; that is, that some vehicle manufacturer could package, style, and market them in such a way that they would penetrate the market segments represented by the missions in a normal new-product manner.

1.2 Data

The basic source of data on automobile usage was derived from the Nationwide Personal Transportation Study (NPTS), conducted by the U.S. Department of Transportation in 1969 (1). The NPTS data is about a decade old but is the only comprehensive source of detailed data on automobile travel for the U.S. as a whole.

The data was collected by interviewing about 6000 respondents throughout the country. The survey contains data collected on daily travel at the discrete trip level including trip length, trip purpose and occupancy. Data was also obtained on household automobile ownership and annual mileage traveled by each automobile owned.

Other sources of data include the 1977 annual report by Motor Vehicle Manufacturers Association (2), studies on electric vehicles by utilities (3) and taxi use data (4).

1.3 Assumptions

One of the basic assumptions in developing the automobile missions was that the travel patterns exhibited by the NPTS will continue in the near future. The sudden rise in gasoline prices contributed to a temporary drop in average annual vehicle kilometers traveled (AVKT) in 1973-74. However, since

1974, AVKT's have resumed their rise, supporting this assumption. The details of the travel patterns could have changed considerably in the last ten years, however. A new survey was taken in 1977 and that data will certainly be of help in updating this mission analysis when it becomes available sometime in 1979.

Another basic assumption behind the analysis is that petroleum resources will become scarce in the future. This scarcity will be passed to the consumer in the form of either higher gasoline prices or restricted supplies, and it is assumed that the consumer will react by placing greater emphasis on fuel costs and fuel consumption in his purchase decisions. This assumption is required to perform the fleet penetration and national petroleum consumption analyses where vehicles are assumed to begin market penetration when their life cycle cost becomes less than their competitors'.

2.0 ANALYSIS METHODS

The seven missions were selected so that the total mission set would meet the following criteria:

1. The mission set should account for a significant proportion of transportation fuel consumption, current or projected.
2. A wide variety of vehicle types should be included, representing both current vehicles and some hypothetical vehicles.
3. A wide variety of travel patterns should be represented.
4. A wide variety of driving conditions should be represented.

All of these criteria were met to large degree.

2.1 Current Vehicle Use Patterns

The basic data used in determining current vehicle use patterns was derived from the NPTS. An analysis was conducted of the annual distances traveled by the U.S. automobile fleet. The distribution of AVKT in the U.S. is shown in Figure 1.

The NPTS data was characterized in terms of the following four basic trip purposes:

- 1) Commuter travel and work related travel
- 2) Family business travel
- 3) Civic, educational and religious travel
- 4) Social and recreational travel.

The daily and annual travel distribution in terms of number of trips and vehicle kilometers traveled is shown in Table I. The trip length frequency distribution for various trip purposes is shown in Table II. The occupancy distribution of vehicles used for various trip purposes is shown in Table III.

2.2 Future Petro-fuel Scenario:

There is little disagreement among energy and transportation policy analysts regarding the basic long term outlook for petroleum. Recent legislation contained in the Energy Policy and Conservation Act of 1975 has already resulted in downsizing of vehicles to meet the mandated fuel economy standards. Recent trends indicate an increasing preference for compact and subcompact automobiles in the U.S. market.

Changes in the demographic characteristics of the U.S., such as lower birth rates in the seventies, coupled with a shortage of petroleum could have a major impact on automobile usage. The net effect of these changes could mean that consumers will be more conscious of fuel economy and an increasing attempt will be made by them to buy vehicles that more closely match their travel needs. This could result in markets for special use vehicles such as the two passenger commuter cars or vacation rental vehicles which have been frequently suggested by EHV proponents. To investigate the applicability of hybrid vehicles to these hypothetical markets, missions were defined for these two "future" vehicles also.

Table I. Percent of Automobile Trips Traveled per Household

Trip Purpose	Percent of		Average Trip length (km)	Trip rate per household		Vehicle-Kilometers per household	
	Trips	Travel		Annual	Daily	Annual	Daily
Earning a living							
Home-to-work	31.9	33.7	15.0	445	1.2	6693	18.4
Related business	4.3	7.9	25.8	61	0.2	1573	4.3
Subtotal	36.2	41.6	16.3	506	1.4	8266	22.7
Family business							
Shopping	15.2	7.5	7.0	213	0.6	1486	4.2
Medical and dental	1.8	1.6	13.4	24	0.1	323	0.8
Other	14.0	10.2	10.4	195	0.5	2032	5.6
Subtotal	31.0	19.3	9.0	432	1.2	3842	10.6
Civic, educational and religious	9.3	4.9	7.5	130	0.4	979	2.6
Social and recreational							
Visiting friends and relatives	8.9	12.1	19.2	125	0.3	2395	6.6
Pleasure driving	1.4	3.1	32.0	19	0.1	610	1.6
Vacations	0.1	2.5	256.0	2	0.05	512	1.4
Other	12.0	15.3	18.2	166	0.4	3034	8.3
Subtotal	22.4	33.0	21.0	312	0.8	6550	17.9
Other and unknown	1.1	1.2	15.0	16	0.04	240	0.6
Total	100.0	100.0	14.2	1396	3.8	19877	54.4
Source: NPTS Data; Report #10, p.13 & Report #7, pp:4&5							

Household automobile ownership and trip purpose	Trip Length - Kilometers					Total
	<9 and less	9-17	17-25	25-33	33 and over	
Earning a living						
One	52.6	21.5	10.6	6.2	9.1	100.0
Two	50.9	20.2	11.2	7.0	10.7	100.0
Three-or-more	51.8	16.9	11.0	6.2	14.1	100.0
All households	51.8	20.1	10.8	6.5	10.8	100.0
Family business						
One	72.8	15.6	5.4	2.3	3.9	100.0
Two	74.9	13.4	6.3	2.1	3.3	100.0
Three-or-more	75.4	12.9	4.6	2.1	5.0	100.0
All households	74.2	14.3	5.6	2.2	3.7	100.0
Civic, educational and religious						
One	79.8	12.3	4.5	1.2	2.2	100.0
Two	77.3	11.9	4.6	2.4	3.8	100.0
Three-or-more	79.5	11.6	4.6	1.5	2.8	100.0
All households	78.8	12.0	4.4	1.8	3.0	100.0
Social and recreational						
One	56.2	16.4	9.8	5.1	12.5	100.0
Two	57.3	17.6	7.5	4.9	12.7	100.0
Three-or-more	53.3	18.9	10.6	3.1	14.1	100.0
All households	56.6	17.1	8.8	4.8	12.7	100.0
All purposes						
One	62.2	17.7	8.2	4.3	7.6	100.0
Two	61.9	14.7	8.3	4.6	10.5	100.0
Three-or-more	61.7	15.7	8.4	3.9	10.3	100.0
All households	62.4	16.8	8.2	4.3	8.3	100.0

Source: NPTS Data, Report #10, p. 81

Table II. Percent of Automobile Trips by Trip Purpose, Trip Length and Household Automobile Ownership

Number of occupants	Major purpose of trip													
	Earning a living			Family business				Educational, civic, and religious	Social and Recreational					All purposes
	To and from work	Related business	Total	Medical and dental	Shopping	Other	Total		Vacation	Visits to friends or relatives	Pleasure rides	Other	Total	
	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent*	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent
1	74.5	62.9	73.2	38.5	43.7	45.9	44.4	33.7	*	36.3	17.0	27.3	30.1	50.9
2	17.6	24.7	18.4	38.2	34.0	31.2	33.0	26.5	*	31.4	41.1	36.0	34.5	27.3
3	4.1	7.5	4.5	12.6	11.5	12.5	12.0	15.8	*	14.8	13.2	12.7	13.6	9.9
4	1.6	2.6	1.8	4.2	6.1	4.7	5.4	10.8	*	8.9	16.2	11.2	10.6	5.7
5	1.0	0.8	1.0	2.2	2.5	3.1	2.7	5.5	*	4.1	7.8	5.2	5.1	2.9
6	0.4	0.5	0.4	3.7	0.8	1.3	1.1	3.6	*	2.2	2.0	4.0	3.2	1.5
7	0.1	--	--	0.3	0.8	0.6	0.7	1.6	*	1.3	2.5	1.5	1.5	0.7
8	0.1	0.1	0.1	--	--	--	--	0.6	*	0.3	--	0.6	0.4	0.2
9 or more	--	0.3	--	--	0.3	0.1	0.2	0.5	*	0.3	--	1.0	0.5	0.3
N/A	0.6	0.6	0.6	0.3	0.3	0.6	0.5	1.4		0.4	0.2	0.5	0.5	0.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total number (000) of daily trips	53,033	6,716	59,749	2,755	25,937	21,407	50,099	14,844	244	14,068	2,036	20,088	36,435	163,964
* Available data not sufficient for analysis SOURCE: Based upon unpublished table P-8 from the Nationwide Personal Transportation Survey conducted by the Bureau of the Census for Federal Highway Administration, 1969-1970.														

Table III. Distribution of Automobile Trips by Number of Occupants for each Purpose of Travel - Residents of Standard Metropolitan Statistical Areas

3.0 MISSION DESCRIPTIONS:

The basic assumption in selecting hybrid vehicle missions is that the mobility of motorists in the post 1985 era will remain the same as it is today. Based on the criteria established for mission selection, spectrum coverage of mission space, and the future petro-fuel scenario, vehicle missions shown in Table IV were selected. Note that the particular characteristics of hybrid vehicles are not considered anywhere in this analysis and selection process; consequently, it may turn out that some missions are inappropriate for hybrid vehicles. However, identification of inappropriate missions may be almost as valuable to hybrid vehicle development and commercialization as identification of promising missions.

3.1 Mission Functions and Payloads

The NPTS data indicates that work trips account for 36 percent of all trips taken and 41.6 percent of AVKT's on a national basis (Table I). The fact that vehicle occupancy of 2 or less accounts for 92 percent (Table III) of the "earning-a-living" trips led us to conclude that a vehicle designed primarily for commuting could be economically feasible; that is, there would be a large enough potential market in a fuel-constrained future to interest a manufacturer in producing such a vehicle. In addition to commuting, the vehicle could be used for most family business. Family business trips with 2 persons or less account for 77 percent of the family business trips. Thus, a 2-passenger commuter and family business vehicle was chosen as the function of a Mission I vehicle. The occupancy distribution for Mission I is shown in Figure 2.

Table IV

Hybrid Vehicle Missions

Functions and Payloads

MISSION I:	COMMUTER AND FAMILY BUSINESS Primary Function: Commuting Travel Secondary Function: Family Business Travel Maximum Payload: 2 Passengers & 50 kg Average Payload: 90 kg
MISSION II:	FAMILY BUSINESS Primary Function: Family Business Travel Secondary Function: Social, Recreational and Other Travel Maximum Payload: 4 Passengers & 100 kg Average Payload: 120 kg
MISSION III:	ALL PURPOSE Primary Function: All Family Travel Secondary Function: None Maximum Payload: 6 Passengers and 200 kg Average Payload: 150 kg
MISSION IV	TAXI/LIMOUSINE Primary Function: Taxi/Limousine Secondary Function: None Maximum Payload: 6 Passengers and 200 kg Average Payload: 200 kg
MISSION V	VACATION RENTAL Primary Function: Vacation Rental Secondary Function: None Maximum Payload: 6 Passengers and 200 kg Average Payload: 300 kg
MISSION VI:	VARIABLE ROUTE DELIVERY TRUCK/VAN Function: Variable Route Delivery Maximum Payload: 2 Passengers & 750 kg Average Payload: 750 kg
MISSION VII:	FIXED ROUTE DELIVERY TRUCK/VAN Function: Fixed Route Delivery Maximum Payload: 2 Passengers and 500 kg Average Payload: 500 kg

Family business travel consists of trips for shopping, health-related trips and other travel involving family business and in the NPTS accounted for 31 percent of all the trips (Table I). The occupancies involved in family business are higher than the occupancies of work trip travel; however, occupancies of four or less accounted for 95 percent of all family business trips. Thus, for Mission II, a 4-passenger vehicle was chosen with the primary function of family business. The vehicle can also perform other types of travel and the occupancy of four accounts for 87 percent of educational, civic and religious trips, and 89 percent of social and recreational trips. The occupancy distribution for Mission II is shown in Figure 3.

The function of a Mission III vehicle, a 6-passenger automobile, was chosen to be the general purpose family vehicle. This vehicle is similar to a full-size automobile in the U.S. market today and performs all family travel functions including vacations and long distance travel. The occupancy distribution for Mission III is shown in Figure 4.

The function of a taxi/limousine was chosen for Mission IV. Taxis accounted for 427 million person trips and 2.9 billion passenger kilometers of travel in 1969, according to the NPTS. The driving environment, consisting largely of stop and go travel, may be well-suited for hybrid application. The distribution of the number of passengers carried for New York City taxis is shown in Figure 5.

In a petroleum-constrained future, it was reasonable to assume that a vehicle large enough to be used comfortably for long distance family vacations may have operating costs, particularly fuel costs, that would be prohibitive

if used on other missions. Since the frequency of such trips is extremely low for most families, they may find it more cost effective to purchase a Mission II vehicle rather than a Mission III vehicle with the intention of renting a special purpose vehicle for vacations. Mission V was selected to test this hypothesis.

Missions VI and VII were chosen as van/truck missions and serve the variable route delivery or service and fixed route delivery functions, respectively. The driving conditions encountered by fleet users while performing these functions make these missions seem suitable for hybrid vehicle application.

3.2 Daily Travel Distributions

This study assumes that the hybrid vehicles' batteries are charged with wall-plug electricity each night. Because this use of wall-plug electricity provides the lion's share of the fuel displacement these vehicles offer and because the annual fuel consumption, battery cycle life, and vehicle life cycle cost of HV's was expected to be strongly affected by the pattern of daily driving distances, considerable effort was expended in defining the daily travel distributions. The driving patterns for the passenger vehicle missions were derived with considerably more rigor than the commercial missions as much more data was available for those missions.

Longitudinal data of the type required for this part of analysis is sorely lacking in the literature. The term "longitudinal" is used here to describe data taken on a single vehicle or group of vehicles over a long period of time. Ideally, such a data base would be a set of diaries of a statistically significant number of vehicles which would include a complete description of each trip taken. One could then determine from such a data base how travel patterns vary over time. The NPTS data and origin-destination surveys are cross-sectional surveys; that is, they ask their respondents what trips were taken on one particular day or set of days and develop a snapshot of what happens in a traffic system on any given day. This data then represents what all vehicles did on a typical day. What is needed is data that represents what a typical vehicle did on all days.

The frequently held assumption that one represents the other is clearly inaccurate. For instance, the distribution of home-to-work distances in the NPTS is roughly a normal distribution whereas any individual's distribution of home-to-work trip distances would have a very strong spike at the distance from

his home to his work. The NPTS distribution really reflects the distribution of how far the respondents lived from work and not the variability in trip distances for that trip purpose. The same can be said for occupancy in home-to-work trips.

For this study, the longitudinal distribution of a vehicle's annual driving in terms of daily travel distances was constructed synthetically by using a Monte Carlo simulation procedure similar to the one used by Schwartz (5) to estimate electric vehicle range requirements.

The basic assumption in this methodology is that the annual distance a vehicle is driven is largely a function of the total number of trips taken and the trip length frequency distribution is assumed to be constant. The number of trips taken on any given day in a year is assumed to have a Poisson distribution. The mean of the Poisson distribution is derived based on the average trip length and annual distance driven. Thus, for a vehicle driven 10,000 km per year, the mean of the Poisson distribution is

$$\mu = \frac{10,000}{365 \times 14.2} = 1.93,$$

where 14.2 km is the average trip length from NPTS. Thus, using the mean of the Poisson distribution, the number of trips taken on any given day can be estimated by the following relationship:

$$p(X) = \frac{e^{-\mu} \mu^X}{X!}$$

where $p(X)$ is the probability of X number of trips on any given day.

A Monte Carlo technique is then used to combine the frequency distributions of trips-per-day and kilometers-per-trip and form the frequency distribution of kilometers-per-day, which is that mission's "travel pattern."

3.2.1 Passenger Vehicle Missions (I,II,III)

The travel patterns for the passenger vehicle missions were developed in an iterative process using the NPTS data as the base. In order to characterize each of the missions in terms of trip length vs. trip purpose, raw data from the NPTS tapes was analyzed. The first few runs were made on the full data base, but this process was so expensive that a random sample of 7000 trips was used for subsequent analyses. The overall trip length frequency distribution from this NPTS sample is shown in Figure 6.

The original intent was to build each mission by combining trip length frequency distributions on a trip purpose by trip purpose basis using Monte Carlo techniques. However, the distributions for the different trip purposes were quite similar to each other so this approach was abandoned for a simpler and more reproducible method. In general terms, the three missions were derived as follows:

- 1) Mission II travel patterns were derived using the NPTS sample distribution minus vacation travel, the Poisson assumption and Monte Carlo construction at three arbitrarily selected AVKT's.
- 2) Mission III travel patterns were constructed from Mission II patterns by adding back in the vacation travel in a specific manner to be described later.

- 3) Mission I was constructed from Mission II by adding more work travel to the lowest AVKT Mission II pattern.

The Mission II functions are intended to represent all family travel except vacation travel. To simulate this, 1600 km per year were subtracted from the national AVKT distribution sampled from NPTS as shown in Figure 7 to construct the AVKT distribution for Mission II.

In order to determine the effect of different AVKT's on HV costs and fuel displacement, three AVKT levels were selected for investigation. These were selected arbitrarily at 14,000 km, 20,000 km, and 26,000 km. The daily travel patterns for each of these AVKT's was constructed using the Poisson distribution and Monte Carlo simulation previously discussed. These patterns were calculated out to 640 km per day. In order to facilitate the simulation of the vehicles, these distributions were compressed by including the days when travel exceeded 244 km in the 160 km to 244 km cell. This resulted in a lower total AVKT for the travel pattern than was input into the process. However, since all the HV designs simulated by the Powertrain Analysis group reached steady state fuel consumption before 160 km of travel, no error in annual fuel consumption was introduced by this compression. A correction is applied in the impact analysis for the reduced AVKT.

The Mission III travel patterns were constructed from the Mission II patterns by adding 1600 km in AVKT. This was done by subtracting days from the low km/day cells and adding them to the 160-224 km cell such that the total number of days was preserved and the AVKT was increased by 1600 km.

The selection of 1600 km per year to represent vacation travel was somewhat arbitrary. The NPTS data indicates that the AVKT for vacation travel was 510 km, but the researchers considered this figure unreliable. Therefore, to accentuate the difference between Mission I and II, the much larger figure of 1600 km was assumed.

The Mission I travel patterns were constructed by adding a home-to-work and work-to-home trip to the daily travel for 2/3 of the year (250 days of commute travel). The length of this trip was taken from the home-to-work trip length distribution from the NPTS at the 50th, 75th, and 90th cumulative percentile levels; i.e., at 16 km, 40 km, and 64 km.

The travel patterns for Missions I, II, and III are shown in Figures 8 through 10. Note that the last cell in each figure is a 64 km cell rather than 8 km like the rest.

3.2.2 Commercial Vehicle Missions (IV, V, VI, VII)

There is a lack of data in the literature on taxi use, especially the daily travel distributions on an annual basis. However, contacts with taxi companies and a New York study on taxis (4) indicated that the AVKT for taxicabs is around 80,000 km and that taxicabs are driven at least sixteen hours a day. This data should be used with care, however, because the taxicab industry is fragmented with a large number of fleets and many owner-operators with varying operations.

Driving conditions and travel patterns vary considerably among shifts also. The first shift sees mostly congested central business district driving while the second shift sees less congested city driving and more suburban driving, as will be discussed in the next section. However, the added complexity of trying to simulate and combine two travel patterns each with its own driving cycle did not seem worth the effort, so only a single shift operation was considered.

The taxi pattern for the first shift was developed from the following assumptions:

- 1) AVKT for the first shift was 48,400 km,
- 2) taxis are driven less than 200 km per day on 90% of the days of the year,
- 3) the shape of the daily travel distribution is approximately normal.

This pattern is shown in Figure 11. Note again that the last cell is not an 8 km cell.

A travel distribution was developed for Mission V, the vacation rental vehicle, based on the assumption that the average vehicle must have an annual travel of about 48000 km for the concept to be commercially viable. The shape of the distribution was chosen arbitrarily.

The daily distributions for Mission VI, the variable delivery route van, were developed on the basis of studies (3) conducted by utilities that use such vans or trucks. Two vehicles representing approximately the 50th percentile and 90th percentile AVKT travel patterns were chosen for this mission with AVKT's of 8620 km and 17,240 km, respectively.

For the Mission VII vehicle, the fixed route vehicle, the daily travel distances of 60 km and 100 km were assumed for the 50th percentile and 90th percentile vehicles. These vehicles are assumed to be driven approximately 240 days a year resulting in annual travel of 14,400 km and 24,000 km.

The daily travel distributions for Missions V, VI, and VII are shown in Figures 12 through 14. Once again, the last cells for Missions V and VI are not 8 km cells. The raw data for all missions is given in the Appendix to this supplementary report.

3.3 Driving Cycles

Previous studies have indicated that the efficacy of hybrid vehicle designs can be very dependent upon the vehicle's driving cycle. Accordingly, a typical driving cycle was constructed for each mission. In order to permit comparisons with test data and other studies, the mission driving cycles were constructed by grouping well known test cycles in such a way that the average speed; stops per mile; and percent of urban, suburban, and highway driving appropriate for the mission were approximated. The original intent was to string the cycles together so that the order of urban-suburban-highway conditions was also preserved, but the additional complexity of simulating vehicles over changing combinations and partial cycles quickly overwhelmed this approach. Also, no satisfactory suburban cycle was found so only the EPA urban, EPA highway, Aerospace Van, and the New York City Emissions cycles were used. The last two cycles are shown in Figures 15 and 16. These two cycles were not followed precisely in the vehicle simulators because the linear acceleration ramps were not considered to be realistic representations of actual driving conditions and because they result in excessively high peak power requirements at the top of the ramps. Instead, the vehicles were allowed to undershoot the profiles slightly such that the peak power requirement matched that required by the 0-100 kph acceleration maneuver.

Those missions with a large variance in daily driving distance have open-ended driving cycles while those with fixed routes or low variance have fixed-length cycles. The mission driving cycles are shown in Table V. The percentages of driving cycles over the missions that result from combining the daily travel patterns with the mission driving cycles are shown in Table VI.

Table V

Mission	Cycle
I Commuter	4 Urban, followed by All Highway
II Family Business	5 Urban, followed by All Highway
III All Purpose	5 Urban, followed by All Highway
IV Taxi	1U, 50N, 1U, 30N, 1H, 30N, 1H, 30N, 2U, 10N, end.
V Vacation Rental	1U, followed by All Highway.
VI Variable Route Van	6 Urban, followed by All Highway
VII Fixed Route Van	46V, 1U, 46V, 1H, 46V, repeat.

U, Urban - EPA Urban cycle
 H, Highway - EPA Highway cycle
 N - New York City emissions cycle
 V - Van cycle

Table VI

Driving Conditions for Hybrid Vehicle Missions

MISSION		AVKT	PERCENT OF ANNUAL TRAVEL			
		km	EPA-U	EPA-H	NY City	Van
I	Low	12,857	84	16		
	Med	18,692	84	16		
	High	24,496	79	21		
II	Low	9,027	86	14		
	Med	14,664	83	17		
	High	21,456	79	21		
III	Low	10,627	79	21		
	Med	16,264	79	21		
	High	23,056	77	23		
IV	-	48,400	28	2	70	
V	-	48,400	11	89		
VI	Low	8,700	93	3		
	High	16,300	91	9		
VII	Low	11,300	38	5		57
	High	22,060	60	22		18

3.4 Performance Requirements

The basic criteria for choosing the performance requirements for hybrid vehicles were safety and non-interference with existing traffic patterns. The performance requirements are specified in terms of top speed, acceleration capability, and gradeability. These requirements are summarized in Table VII.

3.4.1 Sustained Speed

All hybrid vehicle missions described in this report assume freeway capabilities for the vehicle. This results in a requirement for a cruise speed 88 kph (55 mph) with a 25 kph headwind, no grade. However, a no-wind specification is easier to work with in the design phase of the study, so this specification was translated into a top speed of 100 kph with no wind for all vehicles. The specification of a lower top speed would have significant impact on traffic safety. This is based on an analysis of rural highway accidents by Solomon (7). Solomon concluded that the accident involvement rates for low powered vehicles are higher and that accident involvement rate is a function of the difference in vehicle speed from the average speed on the highway. Figure 17 shows the accident involvement rate by variation from average speed as developed by Solomon. Based on his analysis, a speed 16 kph lower than average speed would result in almost a doubling in the accident involvement rate. The prevalent disregard of the 55 mph speed limit by the public further aggravates the situation of lower speed vehicles as has been pointed out by Rosenberg (8) in his analysis of institutional factors affecting electric and hybrid vehicles.

3.4.2 Acceleration

Acceleration requirements are critical in terms of both safety and impact on existing traffic. Several types of acceleration requirements have been specified: low speed acceleration, low speed pass, freeway entrance and freeway merge. The most stringent requirement placed on acceleration capability is the ability to enter onto a freeway. Most freeway on-ramps are elevated with grades of 4% to 6% and lengths between 200-300 meters. Rosenberg has calculated that the accident involvement rate for a vehicle having an acceleration capability of 0-64 kph in 10 seconds will be 3 to 14 times higher if freeway speeds are around 105 kph.

The freeway entrance maneuver acceleration requirement, then, is based on acceleration from a standing start to 64 kph (40 mph) up a 7% grade ramp within 300 meters. A level merging lane long enough to allow acceleration to 80 kph (50 mph) is assumed to be available as is the case in the vast majority of ramps. Through the use of several simulation programs, it was determined that this was essentially equivalent to an acceleration of 0-100 kph in 14 secs on level grade disregarding some minor differences due to gear ratios and shift points. The simpler requirement was chosen because of the greater ease of calculation and simulation.

The introduction of large numbers of low acceleration vehicles in the mix of traffic could have a profound impact on the traffic flow. As mentioned by Todd (9) the slower accelerating vehicles tend to increase the acceptance gap. Herman and Weiss (10) have noted that the low performance car merging from a ramp into a 96 kph stream of given density would wait about six times longer for a gap sufficiently large to avoid turbulence than a car of high

performance. Inclusion of low performance vehicles in the traffic stream tends to increase the critical gap, resulting in delays. The impact of an increase in critical gap is shown in Figure 18, developed by Drew, et al (11). If the inclusion of 10 percent low performance vehicles results in a traffic stream increase of the critical gap from 3 seconds to 4 seconds and assuming an outside freeway lane volume of 1000 vehicles per hour (vph), typical of peak hour freeways in Los Angeles, the ramp capacity decreases from 850 vph to about 500 vph - a 41% reduction in capacity of the ramp. This also would have serious implications in increasing fuel consumption of other vehicles.

The low speed acceleration requirement is similar to current vehicles. This is necessary for safety at intersections as it has been noted by the National Safety Council (12) that acceptance of inadequate gaps (right-of-way violation) is a primary cause of right angle collisions which constitute 16.4 percent of all and 48.5 percent of intersection accidents.

The effect of acceleration capability on capacity of a fixed time signalized intersection is shown in Figure 19, based on a British study cited by Rosenberg. These considerations led to the requirement that hybrid passenger vehicles must have low speed acceleration capability sufficient to keep up with normal traffic which was determined to be 0-50 kph in 6 secs. Most conventional vehicles can accelerate from 0-50 kph in less than 4 secs, but do not normally use this full capability.

The low speed passing and high speed passing requirements were derived from the DOT passing maneuvers.

3.4.3 Gradeability

Estimates of highway grades in U.S. made by Park and Crout (8) show the following distribution:

Grade	Percent of U.S. Highways
3% and less	63.7 (Urban)
4% - 6%	32.0
7% - 9%	3.9
Greater than 9%	0.3

The gradeability requirements are specified so as to ensure minimum speed degradations on freeways, ramps, and city streets. They are adequate for driving on most of the U.S. highways.

3.4.4 Trucks and Vans

The requirements for trucks and vans (Missions VI and VII) are reduced somewhat from passenger cars to levels more representative of current commercial vehicles. The rationale for this is as follows:

- 1) Safety: Because of their larger size and greater visibility to other drivers, they may be able to operate at speeds less than prevailing traffic without incurring a higher accident rate up to a point (assumed to be 10 kph slower than cars). The freeway entrance maneuver is the most demanding and it was assumed that commercial vehicles do not use the freeways as often as cars.

2) Interference: The reduction of capacity caused by the introduction of slow vehicles into the traffic mix is a function of the acceleration capability of the vehicles and the number of vehicles introduced. Since much fewer hybrid trucks are likely to be introduced as compared to the total fleet, some degradation in performance was deemed allowable.

The performance requirements for all missions are shown in Table VII.

3.5 Baseline Vehicle Characteristics

Baseline vehicle characteristics are specified for each mission so that comparisons can be made between alternate vehicles and alternate hybrid vehicle configurations. Vehicle parameters held constant for vehicles being compared are vehicle weight without propulsion system, frontal area, coefficient of rolling resistance and coefficient of drag. Note that the vehicle weight without propulsion system does not include weight propagation effects which are a function of the propulsion system. It is meant to be the minimum weight required to enclose and carry the required payload and a conventional ICE powertrain. All of these characteristics are projections into the 1985 time frame and are meant to represent the average value for that vehicle class rather than the best achievable. Baseline characteristics of the hybrid vehicle missions are shown on Table VIII.

Table VII
Performance Requirements for
Hybrid Vehicle Missions

1. Sustained Speed	Freeway Capability	100 kph
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	Time in Seconds	
	Missions I through V	Missions VI & VII
Low Speed Acceleration (0-50 kph)	6	7
Low Speed Pass (30-55 kph)	4	5
Freeway Entrance (0-100 kph)	14	18
Freeway Merge (60-90 kph)	9	10

3. Gradeability (All Missions)	Percent Grade	Distance, km
Freeway Grades, 90 kph	5	2
Freeway Ramps and City Streets, 50 kph	7	0.4
Driveway Grades, 20 kph	20	0.2

TABLE VIII
Baseline Vehicle Characteristics
for Hybrid Vehicle Missions

MISSION	I 2 Pass.	II 4 Pass.	III 6 Pass.	IV Taxi	V Vac. Rent	VI FRDV	VII VRDV
Vehicle Wt. w/o Propulsion (kg)	500	900	1100	1100	1100	1400	1400
Frontal Area (m2)	1.7	1.8	1.9	1.9	1.9	2.7	2.7
Coeff. of Rolling Resistance	.010	.010	.010	.010	.010	.010	.010
Drag Coefficient	.40	.40	.38	.38	.38	.60	.60

4.0 SUMMARY

Seven vehicle missions were selected and defined for use in assessing hybrid vehicle concepts and are summarized in Table IX. These missions were selected to provide general coverage of current and future vehicle uses and classes. Their travel pattern definitions are based primarily on analysis of the 1969 NPTS travel data. Performance requirements are based on current highway designs and speed limits and the results of studies of performance requirements for safe and non-interfering operation in today's traffic environment. The mission definitions are independent of vehicle technology so even though they were selected and defined for use in assessing hybrid vehicles, they could also be used in assessing the potential of other vehicle technologies such as electric vehicles, turbo-charging, Stirling engines, etc.

**TABLE IX
MISSION SUMMARY**

MISSION No.	I	II	III	IV	V	VI	VII
MISSION TYPE	COMMUTER	FAMILY RUNABOUT	FAMILY ALL PURPOSE	LIMO/TAXI	VACATION RENTAL	VARIABLE ROUTE VAN	FIXED-ROUTE VAN
PASSENGER CAPACITY	2	4	6	6	6	2	2
TOTAL PAYLOAD CAPACITY (kg)	190	375	600	600	600	890	640
AVERAGE PAYLOAD (kg)	90	120	150	200	300	750	500
EPA TEST PAYLOAD (kg)	150	150	150	150	150	150	150
BASELINE CARRIAGE WEIGHT (kg)	500	900	1100	1100	1100	1400	1400
FRONTAL AREA (m ²)	1.7	1.8	1.9	1.9	1.9	2.7	2.7
DRAG COEFFICIENT	0.40	0.40	0.38	0.38	0.38	0.60	0.60
ROLLING RESISTANCE COEFFICIENT	0.010	0.010	0.010	0.010	0.010	0.010	0.010
SUSTAINED SPEED (km/h)	100	100	100	100	100	100	100
ACCELERATIONS (secs):							
0-50 km/h	6	6	6	6	6	7	7
30-55 km/h	4	4	4	4	4	5	5
60-90 km/h	9	9	9	9	9	10	10
0-100 km/h	14	14	14	14	14	18	18
GRADEABILITY:							
5% AT 90 km/h, km	2	2	2	2	2	2	2
7% AT 50 km/h, km	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20% AT 20 km/h, km	0.2	0.2	0.2	0.2	0.2	0.2	0.2
AVKT (km/yr) - MISSION PERCENTILE	12,857 31.5%	9,027 31.5%	10,627 31.5%		48,400 50%	8,700 50%	11,300 50%
DAILY TRAVEL (km/d)							
50%-ile	23	10	11	-	128	20	41
75%-ile	42	31	34	-	193	33	45
90%-ile	78	66	79	-	292	48	52
AVKT (km/yr) - MISSION PERCENTILE	18,692 58.5%	14,664 58.5%	16,264 58.5%	48,400 50.0%	-	-	-
DAILY TRAVEL (km/d)							
50%-ile	45	25	27	132	-	-	-
75%-ile	60	54	59	156	-	-	-
90%-ile	98	99	116	226	-	-	-
AVKT (km/yr) - MISSION PERCENTILE	24,496 77.4%	21,456 77.4%	23,056 77.4%	-	-	16,300 90%	22,060 90%
DAILY TRAVEL (km/d)							
50%-ile	70	43	46	-	-	39	80
75%-ile	86	80	87	-	-	67	92
90%-ile	119	141	159	-	-	107	100
DRIVING CYCLE:	4 URBAN FOLLOWED BY ALL HIGHWAY	5 URBAN FOLLOWED BY ALL HIGHWAY	5 URBAN FOLLOWED BY ALL HIGHWAY	1U, 50N, 1U, 30N, 1H, 30N, 2U, 10N, END	1U, 13H, 2U, 13H, 1U, END	6 URBAN FOLLOWED BY ALL HIGHWAY	46V, 1U, 46V 1HV, 46V REPEAT

U - EPA URBAN CYCLE
H - EPA HIGHWAY CYCLE
N - NEW YORK CITY CYCLE
V - VAN CYCLE

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Figure 1: Distribution of Automobiles by Average Annual Kilometers traveled
Source: NPTS

Figure 2: Mission I Occupancy Distribution

Figure 3: Mission II Occupancy Distribution

Figure 4: Mission III Occupancy Distribution

Figure 5: Mission IV Passenger Load Distribution

Figure 6: Trip Length Frequency Distribution, NPTS Sample

Figure 7: AVKT Distributions for Missions I, II and III

Figure 8a. Mission I Travel Pattern - Low AVKT

Figure 8b. Mission I Travel Pattern - Medium AVKT

Figure 8c. Mission I Travel Pattern - High AVKT

Figure 9a. Mission II Travel Pattern - Low AVKT

Figure 9b. Mission II Travel Pattern - Medium AVKT

Figure 9c. Mission II Travel Pattern - High AVKT

Figure 10a. Mission III Travel Pattern - Low AVKT

Figure 10b. Mission III Travel Pattern - Medium AVKT

Figure 10c. Mission III Travel Pattern - High AVKT

Figure 11. Mission IV Travel Pattern

Figure 12. Mission V Travel Pattern

Figure 13a. Mission VI Travel Pattern - Low AVKT

Figure 13b. Mission VI Travel Pattern - High AVKT

Figure 14a. Mission VII Travel Pattern - Low AVKT

Figure 14b. Mission VII Travel Pattern - High AVKT

Figure 15: Velocity Profile - Delivery Van Emission Cycle

Figure 16: Velocity Profile - New York City Emission Cycle

Source: Solomon, David, Accidents on Main Rural Highways Related to Speed, Driver and Vehicle, U.S. Department of Commerce, Washington, July 1964

Figure 17: Involvement Rate by Variation from Average Speed Day and Night

Figure 18: Possible Capacity of Merging Areas

Source: Cars for Cities, Ministry of Transport
Her Majesty's Stationary Office
London, 1967

Figure 19: Simplified Theoretical Effect of Acceleration of a Traffic Light Controlled Junction (t = Green Phase for an Intersection Approach)

MISSION I-1

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	6.8	6.8	0	0	0
0-8	8.7	15.5	127	1.0	1.0
8-16	11.4	26.9	499	3.9	4.9
16-24	27.2	54.1	1986	15.4	20.3
24-32	11.5	65.6	1175	9.1	29.4
32-40	7.7	73.3	1012	7.9	37.3
40-48	5.5	78.8	883	6.9	44.2
48-56	3.9	82.7	740	5.7	49.9
56-64	3.9	86.6	854	6.6	56.5
64-72	2.0	88.6	496	3.9	60.4
72-80	2.0	90.6	555	4.3	64.7
80-88	1.3	91.9	399	3.1	67.8
88-96	1.3	93.2	437	3.4	71.2
96-104	.9	94.1	329	2.6	73.8
104-112	.8	94.9	315	2.4	76.2
112-120	.6	95.5	254	2.0	78.2
120-128	.5	96.0	226	1.8	80.0
128-136	.4	96.4	193	1.5	81.5
136-144	.4	96.8	204	1.6	83.1
144-152	.3	97.1	162	1.3	84.4
152-160	.2	97.3	119	.9	85.3
160-224	2.7	100.0	1892	14.7	100.0

Annual Vehicle Kilometers Traveled: 12857

MISSION I-2

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	6.8	6.8	0	0	0
0-8	8.7	15.5	127	.7	.7
8-16	4.6	20.1	201	1.1	1.8
16-24	2.9	23.0	212	1.1	2.9
24-32	2.1	25.1	215	1.2	4.0
32-40	8.7	33.8	1143	6.1	10.1
40-48	25.5	59.3	4095	21.9	32.0
48-56	8.3	67.6	1575	8.4	40.4
56-64	8.3	75.9	1818	9.7	50.1
64-72	4.6	80.5	1144	6.3	56.4
72-80	4.5	85.0	1248	6.7	63.1
80-88	2.4	87.4	737	3.9	67.0
88-96	2.3	89.7	772	4.1	71.1
96-104	1.5	91.2	549	2.9	74.0
104-112	1.4	92.6	552	3.0	77.0
112-120	1.0	93.6	425	2.3	79.3
120-128	.9	94.5	408	2.2	81.5
128-136	.7	95.2	338	1.8	83.3
136-144	.6	95.8	307	1.6	84.9
144-152	.4	96.2	216	1.2	86.1
152-160	.4	96.6	228	1.2	87.3
160-224	3.4	100.0	2383	12.7	100.0

Annual Vehicle Kilometers Traveled: 18,692

MISSION I-3

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	6.8	6.8	0	0	0
0-8	8.7	15.5	127	.5	.5
8-16	4.6	20.1	201	.8	1.3
16-24	2.9	23.0	212	.9	2.2
24-32	2.1	25.1	215	.9	3.1
32-40	1.9	27.0	250	1.0	4.1
40-48	1.2	28.2	193	.8	4.9
48-56	4.2	32.4	798	3.3	8.2
56-64	4.1	36.5	898	3.7	11.9
64-72	17.3	53.8	4295	17.5	29.4
72-80	17.2	71.0	4771	19.5	48.9
80-88	5.4	76.4	1656	6.8	55.7
88-96	5.4	81.8	1813	7.4	63.1
96-104	3.4	85.2	1243	5.1	68.2
104-112	3.3	88.5	1301	5.3	73.5
112-120	1.7	90.2	721	2.9	76.4
120-128	1.6	91.8	724	3.0	79.4
128-136	1.1	92.9	530	2.2	81.6
136-144	1.1	94.0	562	2.3	83.9
144-152	0.8	94.8	433	1.8	85.7
152-160	0.7	95.5	399	1.6	87.3
160-224	4.5	100.0	3155	12.7	100.0

Annual Vehicle Kilometers Traveled: 24,496

MISSION II-1

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	20.4	20.4	0	0	0
0-8	26.2	46.6	383	4.2	4.2
8-16	14.2	60.8	609	6.7	10.9
16-24	8.7	69.2	635	7.0	17.9
24-32	6.4	75.6	654	7.2	25.1
32-40	5.8	81.4	762	8.5	33.6
40-48	3.7	85.1	594	6.7	40.3
48-56	2.3	87.4	437	4.9	44.2
56-64	2.2	89.6	482	5.4	50.6
64-72	1.5	91.1	373	4.1	54.7
72-80	1.4	92.5	388	4.3	59.0
80-88	1.0	93.5	308	3.4	62.4
88-96	1.0	94.5	336	3.7	66.1
96-104	.6	95.1	220	2.4	68.5
104-112	.6	95.7	237	2.6	71.1
112-120	.5	96.2	213	2.4	73.5
120-128	.4	96.6	181	2.0	75.5
128-136	.3	96.9	146	1.6	77.1
136-144	.3	97.2	153	1.7	78.8
144-152	.2	97.4	109	1.2	80.0
152-160	.1	97.5	57	.6	80.6
160-224	2.5	100.0	1752	19.4	100.0

Annual Vehicle Kilometers Traveled: 9027

MISSION II-2

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	6.7	6.7	0	0	0
0-8	19.4	26.1	283	1.9	1.9
8-16	12.9	39.0	565	3.9	5.8
16-24	10.0	49.0	730	5.0	10.8
24-32	9.1	58.1	930	6.3	17.1
32-40	7.8	65.9	1025	7.0	24.1
40-48	5.4	71.3	867	5.9	30.0
48-56	4.4	75.7	836	5.7	35.7
56-64	4.3	80.0	942	6.4	42.1
64-72	2.9	82.9	720	4.9	47.0
72-80	2.9	85.8	804	5.5	52.5
80-88	1.9	87.7	583	4.0	56.5
88-96	1.9	89.6	638	4.4	60.9
96-104	1.2	90.8	439	3.0	63.9
104-112	1.1	91.9	434	3.0	66.9
112-120	.9	92.8	382	2.6	69.5
120-128	.8	93.6	362	2.5	72.0
128-136	.6	94.2	289	2.0	74.0
136-144	.6	94.8	307	2.1	76.1
144-152	.4	95.2	216	1.4	77.5
152-160	.4	95.6	228	1.5	79.0
160-224	4.4	100.0	3083	21.0	100.0

Annual Vehicle Kilometers Traveled: 14,664

MISSION II-3

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	1.9	1.9	0	0	0
0-8	9.7	11.6	142	.7	.7
8-16	9.9	21.5	434	2.0	2.7
16-24	8.7	30.2	635	3.0	5.7
24-32	8.7	38.9	889	4.1	9.8
32-40	8.3	47.2	1091	5.1	14.9
40-48	7.3	54.5	1172	5.5	20.4
48-56	6.3	60.8	1197	5.6	26.0
56-64	6.2	67.0	1358	6.3	32.3
64-72	3.9	70.9	969	4.5	36.8
72-80	3.9	74.8	1082	5.0	41.8
80-88	2.8	77.6	859	4.0	45.8
88-96	2.7	80.3	907	4.2	50.0
96-104	2.2	82.5	804	3.7	53.7
104-112	2.2	84.7	867	4.0	57.7
112-120	1.7	86.4	720	3.4	61.1
120-128	1.6	88.0	724	3.4	64.5
128-136	1.3	89.3	627	2.9	67.4
136-144	1.2	90.5	614	2.9	70.3
144-152	1.0	91.5	540	2.5	72.8
152-160	1.0	92.5	569	2.7	75.5
160-224	7.5	100.0	5256	24.5	100.0

Annual Vehicle Kilometers Traveled: 21,456

MISSION III-1

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	20.0	20.0	0	0	0
0-8	25.4	45.4	371	3.5	3.5
8-16	13.1	58.5	574	5.4	8.9
16-24	8.5	67.0	621	5.8	14.7
24-32	6.2	73.2	634	6.0	20.7
32-40	5.8	79.0	762	7.2	27.9
40-48	3.7	82.7	594	5.6	33.5
48-56	2.3	85.0	437	4.1	37.6
56-64	2.2	87.2	482	4.5	42.1
64-72	1.5	88.7	373	3.5	45.6
72-80	1.4	90.1	389	3.7	49.3
80-88	1.0	91.1	307	2.9	52.2
88-96	1.0	92.1	335	3.2	55.4
96-104	.6	92.7	219	2.1	57.5
104-112	.6	93.3	237	2.2	59.7
112-120	.5	93.8	213	2.0	61.7
120-128	.4	94.2	181	1.7	63.4
128-136	.3	94.5	145	1.4	64.8
136-144	.3	94.8	153	1.4	66.2
144-152	.2	95.0	109	1.0	67.2
152-160	.1	95.1	57	.5	67.7
160-224	4.9	100.0	3434	32.3	100.0

Annual Vehicle Kilometers Traveled: 10,627

MISSION III-2

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	6.3	6.3	0	0	0
0-8	18.6	24.9	272	1.7	1.7
8-16	12.1	37.0	530	3.3	5.0
16-24	9.8	46.8	715	4.4	9.4
24-32	8.9	55.7	910	5.6	15.0
32-40	7.8	63.5	1025	6.3	21.3
40-48	5.4	68.9	868	5.3	26.6
48-56	4.4	73.3	836	5.1	31.7
56-64	4.3	77.6	942	5.8	37.5
64-72	2.9	80.5	720	4.4	41.9
72-80	2.9	83.4	804	4.9	46.8
80-88	1.9	85.3	583	3.6	50.4
88-96	1.9	87.2	638	3.9	54.3
96-104	1.2	88.4	439	2.7	57.0
104-112	1.1	89.5	434	2.7	59.7
112-120	.9	90.4	382	2.3	62.0
120-128	.8	91.2	362	2.2	64.2
128-136	.6	91.8	289	1.9	66.1
136-144	.6	92.4	307	1.9	68.0
144-152	.4	92.8	216	1.3	69.3
152-160	.4	93.2	228	1.4	70.7
160-224	6.8	100.0	4765	29.3	100.0

Annual Vehicle Kilometers Traveled: 16,254

MISSION III-3

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	1.5	1.5	0	0	0
0-8	8.9	10.4	130	.6	.6
8-16	9.1	19.5	399	1.7	2.3
16-24	8.5	28.0	621	2.7	5.0
24-32	8.5	36.5	869	3.8	8.8
32-40	8.3	44.8	1091	4.7	13.5
40-48	7.3	52.1	1172	5.1	18.6
48-56	6.3	58.4	1196	5.2	23.8
56-64	6.2	64.6	1358	5.9	29.7
64-72	3.9	68.5	968	4.2	33.9
72-80	3.9	72.4	1082	4.7	38.6
80-88	2.8	75.2	859	3.7	42.3
88-96	2.7	77.9	907	3.9	46.2
96-104	2.2	80.1	804	3.5	49.7
104-112	2.2	82.3	867	3.8	53.5
112-120	1.7	84.0	722	3.1	56.6
120-128	1.6	85.6	724	3.1	59.7
128-136	1.3	86.9	627	2.7	62.4
136-144	1.2	88.1	613	2.7	65.1
144-152	1.0	89.1	541	2.3	67.4
152-160	1.0	90.1	569	2.5	69.9
160-224	9.9	100.0	6938	30.1	100.0

Annual Vehicle Kilometers Traveled: 23,056

MISSION IV

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	5.0	5.0	0	0	0
0-8	0	5.0	0	0	0
8-16	0	5.0	0	0	0
16-24	0	5.0	0	0	0
24-32	1.0	6.0	102	.2	.2
32-40	2.0	8.0	263	.5	.7
40-48	2.0	10.0	321	.7	1.4
48-56	1.5	11.5	380	.8	2.2
56-64	1.5	13.0	329	.7	2.9
64-72	2.0	15.0	496	1.0	3.9
72-80	2.0	17.0	555	1.1	5.0
80-88	2.5	19.5	767	1.6	6.6
88-96	2.5	22.0	840	1.7	8.3
96-104	4.0	26.0	1460	3.0	11.3
104-112	4.0	30.0	1577	3.3	14.6
112-120	7.5	37.5	3176	6.6	21.2
120-128	7.5	45.0	3395	7.0	28.2
128-136	10.0	55.0	4818	10.0	38.2
136-144	10.0	65.0	5110	10.6	48.8
144-152	7.5	70.5	4052	8.4	57.2
152-160	7.5	80.0	4271	8.8	66.0
160-292	20.0	100.0	16488	34.0	100.0

Annual Vehicle Kilometers Traveled: 48,400

MISSION V

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	10.0	10.0	0	0	0
0-8	2.0	12.0	29	.1	.1
8-16	2.0	14.0	88	.2	.3
16-24	3.0	17.0	219	.5	.8
24-32	3.0	20.0	307	.6	1.4
32-40	3.0	23.0	394	.8	2.2
40-48	4.0	27.0	642	1.3	3.5
48-56	2.0	29.0	380	.8	4.3
56-64	2.0	31.0	438	.9	5.2
64-72	2.0	33.0	496	1.0	6.2
72-80	2.0	35.0	555	1.1	7.3
80-88	2.5	37.5	767	1.6	8.9
88-96	2.5	40.0	840	1.7	10.6
96-104	2.5	42.5	913	1.9	12.5
104-112	2.5	45.0	986	2.0	14.5
112-120	2.5	47.5	1059	2.2	16.7
120-128	2.5	50.0	1132	2.3	19.0
128-136	2.5	52.5	1205	2.5	21.5
136-144	2.5	55.0	1278	2.6	24.1
144-152	7.5	62.5	4056	8.4	32.5
152-160	7.5	70.0	4271	8.8	41.3
160-358	30.0	100.0	28345	58.7	100.0

Annual Vehicle Kilometers Traveled: 48,400

MISSION VI-1

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	30.0	30.0	0	0	0
0-8	6.0	36.0	88	1.0	1.0
8-16	8.0	44.0	350	4.0	5.0
16-24	11.0	55.0	803	9.2	14.2
24-32	18.0	73.0	1840	21.1	35.3
32-40	12.0	85.0	1577	18.1	53.4
40-48	5.0	90.0	803	9.2	62.6
48-56	1.5	91.5	285	3.3	65.9
56-64	1.5	93.0	329	3.8	69.7
64-72	1.0	94.0	248	2.9	72.6
72-80	1.0	95.0	277	3.2	76.8
80-88	1.0	96.0	307	3.5	80.3
88-96	1.0	97.0	336	3.9	84.2
96-104	.5	97.5	183	2.1	86.3
104-112	.5	98.0	197	2.3	88.6
112-120	.4	98.4	169	1.9	90.5
120-128	.4	98.8	181	2.1	92.6
128-136	.3	99.1	145	1.7	94.3
136-144	.2	99.3	102	1.2	95.5
144-152	.2	99.5	108	1.2	96.7
152-160	.2	99.7	114	1.3	98.0
160-311	.3	100.0	258	2.0	100.0

Annual Vehicle Kilometers Traveled: 8700

MISSION VI-2

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	30.0	30.0	0	0	0
0-8	2.0	32.0	29	.2	.2
8-16	2.0	34.0	88	.5	.7
16-24	3.0	37.0	219	1.3	2.0
24-32	4.0	41.0	409	2.5	4.5
32-40	10.0	51.0	1314	8.1	12.6
40-48	12.0	63.0	1927	11.8	24.4
48-56	5.0	68.0	949	5.8	30.2
56-64	5.0	73.0	1095	6.7	36.9
64-72	5.0	78.0	1241	7.6	44.5
72-80	5.0	83.0	1387	8.5	53.0
80-88	2.5	85.5	767	4.7	57.7
88-96	2.5	88.0	840	5.2	62.9
96-104	1.5	89.5	548	3.4	66.3
104-112	1.5	91.0	591	3.6	69.9
112-120	1.5	92.5	635	3.9	73.8
120-128	1.5	94.0	679	4.2	78.0
128-136	1.3	95.3	626	3.8	81.8
136-144	1.2	96.5	613	3.8	85.6
144-152	1.0	97.5	540	3.3	88.9
152-160	1.0	98.5	569	3.5	92.4
160-291	1.5	100.0	1234	7.6	100.0

Annual Vehicle Kilometers Traveled: 16,300

MISSION VII-1

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	34.2	34.2	0	0	0
0-8	0	34.2	0	0	0
8-16	0	34.2	0	0	0
16-24	0	34.2	0	0	0
24-32	0	34.2	0	0	0
32-40	0	34.2	0	0	0
40-48	48.6	82.8	7805	69.1	69.1
48-56	9.3	92.1	1765	15.6	84.7
56-64	7.9	100.0	1730	15.3	100.0

Annual Vehicle Kilometers Traveled: 11,300

MISSION VII-2

Driving Distance km	% Days of Year	Cum % Days	Annual Distance km	% AVKT	Cum % AVKT
0	34.3	34.3	0	0	0
0-16	0	34.3	0	0	0
16-32	0	34.3	0	0	0
32-48	0	34.3	0	0	0
48-64	0	34.3	0	0	0
64-80	0	34.3	0	0	0
80-96	49.3	83.6	15835	71.8	71.8
96-112	16.4	100.0	6225	28.2	100.0

Annual Vehicle Kilometers Traveled: 22,060