Electric and Hybrid Vehicle Program Site Operator Program Quarterly Progress Report for October through December 1994 (1st Quarter of FY-1995)

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Executive Summary

The DOE Site Operator Program was initially established to meet the requirements of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. The Program has since evolved in response to new legislation and interests. Its mission now includes three major activity categories:

1. Advancement of Electric Vehicle (EV) technologies
2. Development of infrastructure elements needed to support significant EV use
3. Increasing public awareness and acceptance of EVs.

The 13 Program participants, their geographic locations, and the principal thrusts of their efforts are identified in Table ES-1. The EV inventories of each participant are summarized in Table ES-2.

Table ES-1. Site Operator Program Participants.

Entity	**Principal Thrusts of Program Effort** **a. Fleet evaluation, vehicle test** **b. Infrastructure development** **c. Technical education** **d. Public awareness**
Arizona Public Service Co. Phoenix, AZ	a, b, d
Kansas State University Manhattan, KS	a, b, c, d

Los Angeles Dept. of Water & Power **Los Angeles, CA**	a
Orcas Power and Light Co. **Eastsound, WA**	a, b, d
Pacific Gas and Electric Co. **San Ramon, CA**	a, b, d
Platte River Power Authority **Fort Collins, CO**	a, b, d
Potomac Electric Power Co. **Washington, DC**	a, b, d
Sandia National Laboratory* **Albuquerque, NM**	a
Southern California Edison Co. **Rosemead, CA**	a, b, d
Texas A&M University **College Station, TX**	a, c, d
University of South Florida **Tampa, FL**	a, b, c, d
U.S. Navy **Port Hueneme, CA**	a
York Technical College **Rock Hill, SC**	a, b, c, d
*** Information-sharing agreement**	

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Table ES-2. Site Operator Program active vehicle inventory.

Participant	G-Van	EVcort	Force	S-10	Jet*	Unique	Griffon	TEVan	Other	Total
APS	4	3	1	4	-	2	-	1	1 Solar Colt sedan; 1 Honda CRX; 1 Saturn	18
KSU	-	2	-	-	-	-	-	-	-	2
LADWP	6	-	-	4	-	1**	-	4	5 Prizms	20
OPALCO	-	-	1	-	1	-	-	-	-	2
PG&E	3	1	-	-	-	-	-	-	2 Ford Ecostars	6
PRPA	-	2	-	-	-	-	-	-	-	2

PEPCO	1	1	1	-	-	-	-	-	-	3
SANDIA	-	-	-	-	-	-	-	-	12 Electrica (Escort conversion)	12
SCE	15	-	5	4	-	-	-	2	6 Ford Ecostars, 3 Prizm Sedans, 1 Ranger pickup, 1 bus, 1 Dodge Caravan, 1 BAT sedan, 3 Honda sedans	42
TAMU	15	-	-	3	1	-	-	8	2 race cars	29
NAVY	5	-	-	6	42	-	11	-	2 Grumman	66
USF	2	-	-	10	-	-	-	-	1 Mirage, 1 Dakota	14
YORK	1	-	-	8	-	2	-	-	1 Solectria Force, 1 Escort (Bearskin)	13
TOTALS	**52**	**9**	**8**	**39**	**44**	**5**	**11**	**15**	**46**	**229**
*** = various manufacturers ** = hybrid**										

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Participants' experience with EV operation reflects three unrelated factors:

1. Operating climate and terrain
2. Current battery design and manufacturing technology, and charging/maintenance practices
3. Control and drive component technology and dependability

Factor 1 can noticeably influence the operating range of a vehicle. Factors 2 and 3, in that order, give rise to a great majority of the problems encountered. The effects of vehicle age, weight, and accumulated service mileage are also factors, and are noted by the operators in their service records. To summarize:

- Ambient temperature extremes and other climatic variations decrease vehicle range through both reduced battery capacity and increased accessory usage.
- Battery pack life for a given type is not uniform and frequently much shorter than expected; identical modules may show substantially different service lives.
- Electronic control system and drivetrain components are critical to vehicle operation and failures are not uncommon.

An appraisal of the overall current status of EVs for transportation emphasizes the following:

- Zero-emission vehicles have been mandated to specified percentages of new vehicles sold, by California law. Similar laws have been adopted by Massachusetts and New York and are under consideration in other states.
- For successful use of electric vehicles, conditions must be favorable, typically involving short-range service and infrastructure (i.e., charging and service) availability. Climate and terrain also impose limitations.
- Evaluation and test activities to date reflect the need for technology advances. Improved battery chemistry, design, and manufacturing practices are needed if adequate dependability is to be achieved. Powertrain and control system design will necessarily reflect battery technology changes, although control and powertrain design philosophy is potentially flexible. Examples are AC versus DC drive power, and the use (and operational problems) of regenerative braking. Some problems with weight overload when converting a chassis designed for ICE power have begun to surface.
- The additional cost of an EV over conventional ICE vehicles is largely in purchase price. Operating costs appear to be competitive.
- Vehicles representing relatively new designs (e.g., Solectria and US Electricar) are presenting a variety of equipment and operational problems to the users.
- Further effort is needed in hybrid vehicle development to achieve the necessary operating performance and overall dependability.
- Batteries and charging equipment continue to present generic problems, even in otherwise proven EV systems. Fast-charge technology is now under active investigation with several options available, and standardized testing protocols are being developed. A companion effort, the Rapid Battery Interchange Program, has been started at Pacific Gas and Electric Co.

Program Management covered a spectrum of activities:

- Reports of Program status.
- Public awareness activities.
- Purchase orders totaling 42 pickup conversions have been placed with two vendors subsequent to the Site Operator Users Task Force (SOUTF) bid evaluations. These units will be factory-equipped with the current version of the Mobile Data Acquisition System (MDAS). To date, a few deliveries have been made.

A Program Experience Overview, the result of analyzing Site Operator inputs, provides an insight into the variables that can affect electric vehicle performance and operating cost. These variables must be considered when making comparisons with conventional ICE-powered vehicles.

Graphic treatments of composite data for the reported G-Van, Escort, Chevrolet S-10, and VW Pickup, highlight the intrinsic differences among these vehicle types, as well as reflecting site-to-site differences attributable to operating requirements and environmentally seasonal influences. Separate presentations are made of (1) energy costs; (2) maintenance costs; (3) consolidated (all sites) energy costs; and (4) service/repair costs for specified activity groups. The influences of vehicle type/weight, operating service requirements, operating environment, and vehicle age/cumulative usage are inherent in the results of the analysis.

It is noted that lighter-weight EVs (for example, the EVcort) have better performance and maintenance records. The apparent absence of such information from the graphic composite data reflects two factors:

1. Not all Site Operators report specific operating and maintenance data;
2. Some data are provided in a format that is not compatible with our analytical algorithm.

Conclusions

The conclusions reached from the overview results were:

- The larger, heavier G-Vans consume more energy than the smaller, lighter, Ford Escort, or the pickup trucks (i.e., Chevrolet S-10 or Volkswagen pickup).
- An electric vehicle that is used sporadically will use more energy/mile than one that is used more often, and for longer trips at uniform speeds. This is shown by the Ford Escort data.
- "Opportunity Charging" significantly affects the accuracy of the reported Site Operator data because energy added to the system during "opportunity charging" is often not recorded.
- Charging technology problems tend to impede effective utilization of EVs. These problems relate to:

    a. Passenger comfort power demands
    b. On-board charging equipment rate limitations
    c. Charging equipment incompatibility with infrastructure features governed by local ordinance.
    d. Effective solar charging has regional limitations, but may be economically feasible when surplus power can be sold via a grid connection.

- Routine maintenance costs are comparable for the four (4) types of vehicles reported, although major maintenance needs can make this difficult to detect.

Recommendations

The following recommendations are made as result of the data analysis:

- Use of in-vehicle data acquisition systems will be used to eliminate the effect of unrecorded "opportunity charging," and reduce the labor required to edit data records containing errors.
- The area of charging technology should be surveyed to identify (and rank) its related problems and candidate approaches to controlling and minimizing their effects.
- More sites should report data utilizing the Site Operator Database. This would provide a larger data sample, give more reliable results, and reduce the amount of special handling required for

data reported utilizing other media.
- A structured investigation of rapid charging should be conducted by implementing rapid chargers at selected sites and monitoring the effects on current vehicle battery system.

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Introduction

The Site Operator Program was initially established by the Department of Energy (DOE) to incorporate the electric vehicle activities dictated by the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976. In the ensuing years, the Program has evolved in response to new legislation and interests. The Program currently includes twelve sites located in diverse geographic, metrologic, and metropolitan areas across the United States (see Figure 1). Information is shared reciprocally with a thirteenth site, not under Program contract. The vehicles are operator-owned, except for two Griffon vans.

The Mission Statement of the Site Operator Program includes three major activities:

1. Advancement of electric vehicle technologies
2. Development of infrastructure elements necessary to support significant electric vehicle use; and
3. Increasing the awareness and acceptance of electric vehicles (EVs) by the public.

Table 1 indicates the EVs in each of the Site Operator fleets. Table 2 provides baseline information on several EVs currently in use by the Site Operators, or which have evolved to the point that they may be introduced in the near future.

Table 1. Site Operator vehicle fleet.

Arizona Public Service Company (APS)

1.	Unique sedan	2 ea.
2.	G-Van (cargo)	2 ea.
3.	G-Van (passenger)	2 ea.
4.	EVcort sedan	3 ea.
5.	Solar Colt sedan	1 ea.
6.	TEVan	1 ea.
7.	Honda CRX	1 ea.
8.	Saturn	1 ea.
9.	Solectria	1 ea.
10.	S-10	4 ea.
	TOTAL	**18**

NOTE: Does not include 3 vehicles donated to local organizations

Kansas State University (KSU)

1. EVcort sedan	2 ea.
TOTAL	**2**

Los Angeles Department of Water and Power (LADWP)

1. G-Van (passenger)	4 ea.
2. G-Van (cargo)	2 ea.
3. Unique hybrid passenger	1 ea.
4. TEVan	4 ea.
5. S-10 pickup	4 ea.
6. Prizm sedan	5 ea.
TOTAL	**20**

Orcas Power and Light Company (OPALCO)

1. Escort	1 ea.
2. Solectria Force	1 ea.
TOTAL	**2**

Pacific Gas and Electric Company (PG&E)

1. G-van (passenger)	2 ea.
2. G-van (cargo)	1 ea.
3. Ecostars	2 ea.
4. EVcort	1 ea.
TOTAL	**6**

Platte River Power Authority (PRPA)

1. EVcort 2 ea.

TOTAL 2

Potomac Electric Power Company (PEPCO)

1. G-Van (passenger)*	1 ea.
2. Solectria Force	1 ea.
3. EVcort	1 ea.

TOTAL	**3**

* Not currently in service

Sandia National Laboratory

1. Electrica (Escort conversion)	12 ea.
TOTAL	**12**

Southern California Edison Company (SCE)

1. G-van (passenger)	9 ea.
2. G-van (cargo)	6 ea.
3. Ford Ecostar	6 ea.
4. Solectria Force	5 ea.
5. Electricar pickup (S-10)	4 ea.
6. BAT sedan	1 ea.
7. Pickup (Venus Motors) (Ranger)	1 ea.
8. Sedan, Prizm	2 ea.
4. TEVan	5 ea.
5. Bus (Clean Air Transit)	1 ea.
6. Honda sedans	3 ea.
7. Van, Dodge Caravan	1 ea.
TOTAL	**42**

* Not currently in service

Texas A&M University (TAMU)

1. G-van	15 ea.*
2. Jet	1 ea.
3. TEVan	8 ea.
4. Race Car	2 ea.
5. S-10 Pickup	3 ea.
TOTAL	**29**

* Includes consortium vehicles

U.S. Navy (NAVY)

1. Jet (various) 42 ea.
2. Grumman Van 2 ea.

3. S-10	6 ea.
4. G-Vans	5 ea.
5. Bedford Vans	5 ea.
6. Griffon Van	6 ea.
TOTAL	**66**

University of South Florida (USF)

1. G-Van (passenger)	2 ea.
2. Chevy S-10 Pickup	10 ea.
3. Dakota	1 ea.
4. Mirage	5 ea.
TOTAL	**14**

York Technical College (YORK)

1. G-Van	1 ea.
2. Escort (Bearskin)	1 ea.
3. Unique Sedan	2 ea.
4. S-10 Pickup	8 ea.
5. Solectria Force	1 ea.
TOTAL	**13**

Total Site Operator Program 229

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Table 2. Baseline vehicle information on selected electric vehicles.

VEH NAME	G-Van	EVcort	Force	S-10	TEVan	ECOSTAR
MFG	Conceptor	Soleq	Solectria	Solar Car	CHRYSLER	FORD
BODY	VAN-PSG/CRGO	SEDAN	SEDAN	PICK-UP	MINI-VAN	STAT. WAG.
NO. PASS	7/2	4	2+2	2	7	2
BATT TYPE	LEAD-ACID	LEAD-ACID	LEAD-ACID	LEAD-ACID	NI-FE	NA-S
ODUL VLT	6	6	12	6	6	-
NO. MODUL	32	18	12	20	30	-

SYST VOLT	216	108	144	120	180	336
CHARGER	OFF BOARD	ON BOARD	ON BOARD	ON BOARD	ON BOARD	-
WEIGHT(GVW)	8600 lbs	3980 lbs	2450 lbs	3200 lbs	~6000 lbs	3950 lbs
WEIGHT(CURB)	7670 lbs(Pass) 7050 lbs(Cargo)	3560 lbs	-	3500 lbs	-	3200 lbs
MOTOR/HP	DC/60 hp	DC/42 hp	AC/25-DC/32	DC/28	DC/55	AC/75 hp
EST RANGE	60 MI.	60 MI.	46 MI.(FUDS)	40-70 MI	120 MI.	100 MI.
REGEN BRK	YES	YES	YES	OPTIONAL	YES	YES
Note: VW-Pickup curb weight = 3370 lbs; Griffon Van curb weight = 5513 lbs; Mitsubishi Mirage curb weight = 2590 lbs, Mitsubishi Mirage GVW weight = 3417 lbs.						

VEH NAME	**IMPACT**	**LA 301**	**ELECTRON-TWO**	**FEV**	**RAM 50 TRUCK**	**E1**
MFG	GM	CLN AIR TRNS	SOLAR ELECTR	NISSAN	EVA	BMW
BODY	SEDAN	SEDAN	SEDAN	SEDAN	PICK-UP	SEDAN
NO. PASS	2	4	2	2	2	4
BATT TYPE	LEAD-ACID	PB-A w/HYBRID	LEAD-ACID	NI-CAD	LEAD-ACID	NA-S
MODUL VLT	10	6	6	-	6	-
NO. MODUL	32	32	18	-	20	-
SYST VOLT	320	216	108	-	120	120
CHARGER	ON BOARD	ON BOARD	-	ON BOARD	-	-
WEIGHT	2200 lbs	3894 lbs	3100 lbs	1984 lbs	3500 lbs	2600 lbs
MOTOR/HP	2 ea AC/57 hp	57	DC/23 2 ea	DC/38	DC/45	
EST RANGE	80 MI	40-60 MI*	45-65 MI	100 MI	50-70 MI	155
REGEN BRK	YES	YES	-	YES	-	-
* BATT. ONLY; 150+ MI AS HYBRID						

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The Program is currently managed by personnel of the Electric and Hybrid Vehicle Program at the Idaho National Engineering Laboratory. The current principal management functions include:

- Coordination of Site Operator efforts in the areas of public awareness and infrastructure development (program-related meetings, and educational presentations).
- Technical and financial monitoring of programmatic activities, including periodic progress reports to DOE.
- Data acquisition, analysis, and dissemination. The data from the Site Operators are made available to authorized users through the Idaho National Engineering Laboratory (INEL) Site Operator Database.

The ultimate thrust of program activities varies among sites, reflecting not only the Operator's business interests but also geographic and climate-related operating conditions. These considerations are identified below for each Program Status entry.

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Program Management

The Program report for the fourth quarter of FY-94 was issued.

Modification of the financial agreements with current participants is being discussed.

Orders for the remaining 22 electric vehicle conversions from GE/Spartan have been canceled by this supplier. The MDAS units originally slated for installation in many of these units from GE/Spartan will be used in other operator-sponsored vehicles.

Initial laboratory tests of two different versions of the Sigma Tec systems MDAS unit have been completed at the INEL, and the results reported. Further laboratory tests of the more advanced version are planned, to provide a baseline for evaluating in-vehicle performance of this device.

Ten MDAS units are on order for use in the EV American Test Support effort involving testing at Virginia Electric Power Company.

Review of contract renewals for Program participants is completed. Task recommendations will be based on funding availability. The PEPCO contract has been renewed; others will be renewed as they expire.

The Interface Agreement between the Site Operator Program and EV America is in the review process.

The annual Site Operator Users Task Force Meeting was held during November 1994 in Washington, DC.

Table 3. Recommended MDAS distribution for S-10 pickup conversions.

Site	No. Spartan	**W/MDAS**	**No. Electricar**	**W/MDAS**	**EV Operating Envionment**
APS	6	4	-	-	Warm-hot/flat/urban
KSU	4	2	-	-	Warm-cold/flat-suburban
LADWP	-	-	5	3	Warm-cool/mixed/urban
PEPCO	2	2	2	2	Hot-cold/mixed urban
PRPA	5	3	-	-	Warm-cool/mixed/suburban-rural
PG&E	-	-	5	3	Warm-cool/mixed/urban-suburban
SCE	3	2	3	2	Warm-cool/mixed/urban-suburban freeway
TAMU	-	-	3	3	Hot-cool/flat/rural-suburban
USF	2	2	-	-	Hot-cool/flat-urban-freeway
YORK	-	-	2	2	Hot-cool/flat/suburban-urban
Total	**22**	**15**	**20**	**15**	-

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Program Experience Overview

Because a principal interest, and corresponding activity, of the Site Operator Program is vehicle performance evaluation, various data acquisition and analysis methods and equipment are in use. Most recently, installation of the Mobile Data Acquisition System in several new Program vehicles will provide real-time operating data. However, these vehicles will not be operated all at a single site, nor under closely similar conditions. It then becomes necessary to arrive at a sound basis for data comparisons, groupings, and statistical interpretations. The objective here is to determine how many vehicles must be tested, and for how long a time interval, to assure a 95% confidence level in the data.

Two reports were transmitted to DOE on September 9, 1994:

1. *"Application of the Technique for Estimating the Number of Electric Vehicles and Length of Time Necessary for a Field Test to G-Van-C Data"*
2. *"Technique for Estimating the Number of Electric Vehicles and Length of Time Necessary for a Field Test."*

Report 1 presents a classical statistical analysis of field test data for G-vans operated by Public Service Electric and Gas Company. Report 2 applies multivariate statistical methods to operating data from a Mobile Data Acquisition System installed in an electric vehicle from Virginia Power Corp. and tested at the Idaho National Engineering Laboratory.

The method, data, and the consequent calculations are presented in these two reports, and are available from the INEL Vehicle Database(s) within the Automotive Systems and Technology Department. The MDAS, combined with the multi-variate data analysis techniques will provide about 7 times better precision than the manual data acquisition method used to acquire the PSE&G, G-Van-C data. This improvement will allow the average vehicle efficiency to be measured with 95% confidence with the number of samples computed as 649.

Thus, with three vehicles per site as the lower limit recommended in Report No. 1, the classical analysis presented herein predicts that 216 samples are required; and with four vehicles per site, 162 samples are required. This result appears consistent with the trend of the results presented in Report No. 1, which demonstrated that for three similar vehicles, the results were just beginning to converge to the 95% confidence interval within 50 samples per vehicle.

MDAS units were tested at the INEL to compare with the Laboratory Data Acquisition System (LDAS). The MDAS was limited to 16 channels, a substantially increased flexibility as needed. The precisions are eight binary bytes for the MDAS and 16 for the LDAS. Sampling frequencies are adjustable for both systems; the data from either system can be normalized to give comparable results. The reports of this investigation are in publication.

At this time, there exists no comprehensive data to define the battery life for the seven vehicles analyzed, either in terms of the life of modules within the battery pack or in terms of the life of the battery pack as a whole. However, the INEL Energy Storage Test Laboratory has acquired limited data for a wide range of vehicle applications while advising the Site Operators concerning replacement of battery pack modules that failed prematurely. Based on this experience, it seems reasonable to estimate that some lead-acid battery modules, in a fleet operation environment, will begin to fail prematurely within 200 charge cycles. Thus, to assure that 95% confidence results can be achieved within the test time interval, and within the life of a battery module or pack, then four similar vehicles, tested for 162 charge cycles, must be recommended. As both MDAS and maintenance data are acquired, showing battery life cycle information, this estimate of battery life can be revised, as necessary.

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Summary

The DOE Site Operator Program currently receives input from 14 sites in the U.S. The participants are public utilities, educational institutions, a National Laboratory, and the U.S. Navy. (During this reporting period, no input was received from the Navy.) The number of electric vehicles now in use or undergoing test evaluations exceeds 175, ranging in age from new to twelve years. Body styles are mainly for utility (van or pickup) or passenger service.

Program participant efforts reflect varying combinations of day-to-day use, laboratory testing and evaluation, and successful promotion of public awareness by demonstrations, exhibits, and media dissemination of related activities and information.

The foregoing status entries provide more specific information concerning the Program participants and their overall interests, their programmatic activities, and their experiences with electric vehicles and accompanying problems.

The principal operating problem reported is a decrease in vehicle range, usually a direct result of battery pack problems, but also a function of the climate, especially the ambient temperature, in the operating environment.

The principal maintenance problems relate first to batteries and then to failures of electric components in the control systems and the powertrain.

Program management activities relate to issuance of reports, communication with sponsors (DOE) and cooperating institutions, determination of program goals/objectives, and evaluation of advanced EV-related components and systems.

An overview of Program experience, derived from the operator inputs, demonstrates unequivocally the differences in energy and maintenance costs for operating the principal types of electric vehicles used by the participants. A categorical breakdown of service/repair costs in \$/km identifies the principal problem groups associated with each vehicle type. This information, presented in Appendix A, is not all-inclusive of the Site Operators; for the others, the data were either not provided or were submitted in a form that is incompatible with the Program's data-handling algorithms.

It is for these reasons that in-vehicle automated data acquisition systems will be implemented in the near future. The DOE data requirements are currently being developed for automated data systems, and a summary of these developments will be presented in a future Site Operator Quarterly report.

Despite apparent commonalities of interests among the Program participants, their individual contributions have been adequately diverse, for a variety of reasons related to equipment, operating environment, operating philosophy, and the overall objectives of each participant. The three major categories of the Program Mission appear to be well served.

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