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Consortium Developing
Advanced Transportation
Technologies

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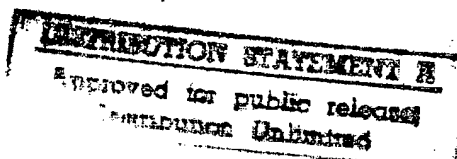
Mr. Richard A. White
San Francisco Bay Area
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DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

ELECTRIC AND HYBRID ELECTRIC VEHICLE TECHNOLOGIES

COOPERATIVE AGREEMENT MDA972-95-2-0011

QUARTERLY REPORT July 1 to September 30, 1996



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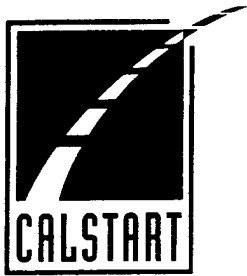
PER: LESLIE WOSLEY - CONTRACT MANAGER

(818) 565-5608

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Prog.: Consolidated Elec. & Hybrid Vehicle Tech. Dev. for Military & Com. Application & Cluster Dev. Planning

CALSTART Participant: CALSTART						To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %		
959,267	1,429,105	9,557,599	5,152,462	922,156	1,699,039	5,152,462	46.09%		
0	0	0	0	0	0	0			
0	0	0	0	0	0	0			
0	0	0	0	0	0	0			
Totals 959,267	1,429,105	9,557,599	5,152,462	922,156	1,699,039	5,152,462	46.09%		



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**1. OPTIMIZED 30kW TURBINE/FLYWHEEL
HYBRID ELECTRIC VEHICLE**

Project Manager: Rosen Motors

This project has been modified. See discussion of "Catalytic Combuster/Hybrid Electric Bus Demonstration" program. The official request for modifying the program was submitted to Elaine Ely on September 25, 1996 with a clarifying letter sent on October 6, 1996 (see Appendix A).

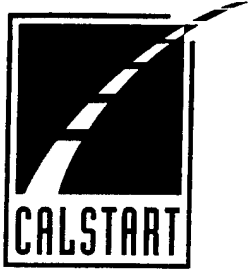


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2. **ALUMINUM RUNNING CHASSIS FOR CIVILIAN USE (RCP-4C)**

Project Manager: Amerigon Incorporated

This project has been modified. See discussion of "Running Chassis II." The official request for modifying the program was submitted to Elaine Ely on September 25, 1996 with a clarifying letter sent on October 6, 1996 (see Appendix A).



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3. **HEAVY-DUTY HYBRID ELECTRIC DRIVE TRAINS**

Project Manager: Santa Barbara Air Pollution Control District

DARPA Program Manager Robert Rosenfeld conducted a review of this program with CALSTART staff in Burbank. After the review and some deliberation, it was recommended that this program be significantly modified. With the departure of FMC from the project, the interest in the effort proposed by this team has waned. It is now our recommendation that the garbage truck program, as presently contracted, be dropped and that CALSTART should identify a suitable and related project to replace it.

Meanwhile, the SBAPCD sent CALSTART an invoice for \$40,000 to cover costs incurred with the 5 ton truck program prior to the decision to terminate the project. CALSTART will review the invoice and will make a recommendation to DARPA during the next quarter.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: HD Hybrid Electric Drive Train		CALSTART Participant: SB Air Pollution Control Dist.				To: Sept. 30, 1996	From: July 1, 1996
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
36,427		887,993		41,497			100.00%
Totals	36,427	0	887,993	41,497	0	0	100.00%



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4. ENERGY MANAGEMENT CONTROLLER

Project Manager: Delco Electronics

This project remains behind schedule. Delco Electronics has still not signed its companion contract with the New York City Transit Authority. No significant technical progress has been achieved. (See attached letter from Delco Electronics.)

Not satisfied with the program to date, CALSTART will be working with Delco to re-evaluate the purpose and direction for this program during the upcoming quarter.



Power Control Systems

CALSTART
John Boesel
Executive Vice President
3601 Empire Avenue
Burbank, CA 91505

17 June 1996

Re: Energy Management Controller Contract, Electric and Hybrid Electric
Technology Development for Military and Commercial Applications (RA-94-24)

Dear Mr. Boesel,

As you know, we continue to expand our efforts in support of electric vehicles. In keeping with these efforts, the Power Control Systems (PCS) business unit of Delco Electronics in Torrance joined with Allison Transmission Division and Delphi Engine and Energy Management last year in a multi-year development. That multi-year development is designed to put in production a Heavy Duty (HD) Component Set for a bus hybrid propulsion system.

The development project is funded, in part, by DARPA but has been awaiting final contract award for a major portion of the funds from the New York City Transit Authority (NYCTA). The above referenced controller work was originally slated to be tested (in prototype) on a hybrid bus so we've been delaying the start of this project to coordinate it with the HD Component Set development work.

I know that this has resulted in a major slip in the schedule but the execution of the project and timely completion, now planned for this year, will benefit considerably from coordination with the NYCTA development. Part of the benefit is technical since the HD component set is planned for production. An additional benefit is that key staff will be more readily available (as you know, we're in production with the EV1 which has taxed our internal resources).

If you wish additional specific information or further discussion, please feel free to call me at (310) 517-5748 or via fax (310) 517-5727.

Dr. Lawrence S. Wnuk

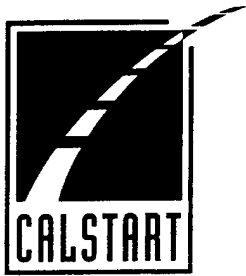
A handwritten signature in black ink, appearing to read "Lawrence S. Wnuk". The signature is fluid and cursive, written over the typed name.

Manager, Heavy Duty
Power Control Systems

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Energy Management Controller

CALSTART Participant: DELCO Electronics				To: Sept. 30, 1996		From: July 1, 1996		
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %	
102,600	2,000	513,800	91,000	65,000	18,000	91,000	82.29%	
Totals	2,000	513,800	91,000	65,000	18,000	91,000	82.29%	



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5. **HYBRID ELECTRIC BATTERY**

Project Manager: Bolder Technologies

CALSTART contacted both Bolder Technologies and Johnson Controls to discuss the status of the project. Representatives from both organizations indicated they were still reviewing their plans and expected to make a final decision during the next quarter.

Due to the lack of direction from Bolder Technologies and Johnson Controls, CALSTART does not yet have a contract in place to complete this project.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: HEV Battery System		CALSTART Participant: Bolder Technology				To: Sept. 30, 1996	From: July 1, 1996
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
100,000		740,000		120,000			100.00%
Totals	100,000	0	740,000	0	120,000	0	100.00%



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6. **ELECTRIC AND HYBRID ELECTRIC VEHICLE DATA
ACQUISITION SYSTEM**

Project Manager: CALSTART

CALSTART is in the final stages with the drawings for the new Aluminum box which houses the main processor board and storage unit. CALSTART is also in the final stages for the 2nd release of the prototype due in early November 1996.

Schematic and Housing for the Keypad/Display

The schematic layout corrections has been finalized. Pending the final stages for the Analog and Digital Board, the 2nd prototype release is scheduled for early November release.

Schematic for Analog/Digital Board

Due to the incorporation of additional parts, the schematics for both the Analog and digital boards needed to be modified. Release of these boards is also scheduled for early November release.

Software Drivers

CALSTART is continuously testing and debugging the software low-level codes. With the 2nd release of the PCB, CALSTART is ready to test the latest software driver release.

Other works in progress

The final stages for the new aluminum box will be done with the 2nd release of the Analog and Digital Board.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Data Acquisition

CALSTART Participant: CALSTART Data Acquisition				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
16,667	27,012	116,669	122,613	16,666	122,613	122,613	-5.09%
Totals	27,012	116,669	122,613	16,666	122,613	122,613	-5.09%



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7. HEAVY-DUTY HYBRID ELECTRIC VEHICLE EMISSIONS STUDY

Project Manager: Natural Resources Defense Council

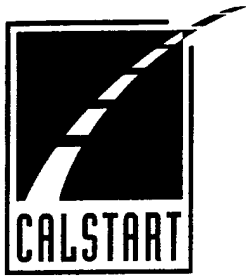
The NRDC has been delinquent in submitting the quarterly reports to date. In June, CALSTART received three quarterly reports from the NRDC. The reports reveal that the following work has been performed to date:

- The basic methodology for the study was identified after reviewing thoroughly literature from sources such as the Society of Automotive Engineers and the Department of Energy.
- The determination was made that energy consumption data currently available for a wide range of vehicle/engine configurations will form the basis of pollutant emissions estimates.
- Baseline and Hybrid vehicle configurations - a four-stroke diesel, a four-stroke natural gas transit bus, a four-stroke diesel garbage truck and a four-stroke diesel delivery truck emissions will be studied. In the transit bus category, diesel, natural gas, methanol and propane fuels emissions will be charted in both the externally-fired Stirling Engine and the gas turbine engine. Further, a methanol fuel-cell transit bus formaldehyde emissions will be weighed against the toxicity of the benzene and particulate emissions from diesel fuel. Only diesel APU configurations will be examined in garbage trucks.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Hybrid Electric Air Emission Study

CALSTART Participant: NRDC									
To: Sept. 30, 1996					From: July 1, 1996				
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %		
32,000		168,000		32,000			100.00%		
Totals	0	168,000	0	32,000	0	0	100.00%		



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8. PROGRAM MANAGEMENT AND ADMINISTRATION

Program Manager: **CALSTART**

CALSTART continues to negotiate and process contracts with the companies that funded with FY96 funds as well as managing the on-going RA94 and FY95 programs. The Program Participant Manual, a document used to establish formal policies and procedures between CALSTART and the individual program managers, was re-written; greatly simplified and has been well received.

Linda Wasley has replaced Paul Smith as the Contract Administrator for CALSTART. Linda has an MBA from Pepperdine and considerable work experience in the administration of projects. Linda's organizational skills, coupled with legal advice from Alf Brandt (General Counsel) and the on-going expertise contributed by John Boesel and Paul Helliker creates a team prepared to give CALSTART clients and funding agencies the best service in all contract matters.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Program Management

CALSTART Participant: CALSTART				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
66,000	27,520	337,000	165,263	66,000	165,263	165,263	50.96%
Totals	27,520	337,000	165,263	66,000	165,263	165,263	50.96%

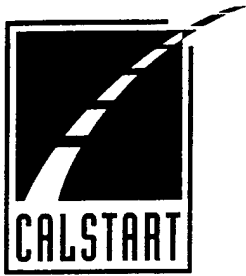


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**9. ALUMINUM RUNNING CHASSIS FOR MILITARY USE
(ARC4-M)**

Project Manager : Amerigon Incorporated

This project has been modified. See discussion of "Running Chassis II." .
The official request for modifying the program was submitted to Elaine Ely
on September 25, 1996 with a clarifying letter sent on October 6, 1996 (see
Appendix A).



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10. ELECTRIC AIRPORT SHUTTLE BUSES

Project Manager: Santa Barbara Air Pollution Control District

It has been recommended that this program, as originally designed, be dropped. CALSTART may still be able to identify replacement buses and systems. However, the project should be put on "hold - indefinitely."



Defense Advanced Research Projects Agency
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**11. NAVAL AIR STATION ALAMEDA:
CLUSTER PLANNING AND PROJECT HATCHERY NORTH**

Project Manager: CALSTART

Project Hatchery Alameda

On July 22, 1996, a successful Grand Opening of Project Hatchery Alameda was conducted. Over 250 people attended from private industry, government, and the community. Speakers included Charles Inbrecht, Chairman of the California Energy Commission and Sandre Swanson, District Director for Congressman Ronald V. Dellums. The event generated considerable favorable coverage from electronic and print media. (See attached new article.)

The CALSTART Project Hatchery Alameda facility is at 80% of capacity as of September 30, 1996. "Hatchery Associates" service provider group is growing and has provided direct support to new and established tenant companies in accounting, legal matters, and business planning. There are eleven organizations at PHA in addition to the operation of CALSTART/North. Additions since the Grand Opening include:

- ◆ CTJ Corporation is managing transportation technology transfer, export and manufacturing ventures with emphasis on the Pacific Rim.
- ◆ Forem Metal Manufacturing is a company of former baseworkers modifying truck bodies to increase access and payload. They have already applied for lease of facilities at NAS for large-scale rework activity.
- ◆ Zebra Motors showcased their prototype high-performance electric sports car at our Grand Opening and have since moved R&D into PHA to develop the production model leading to DOT certification. Zebra has also applied for a facility at NAS to grow into as they ramp up to a production goal of 2000 vehicles a year at Alameda.

Renovation of Hangar 20, home of PHA, is effectively complete. When the Alameda Bureau of Electricity completes its transfer work, the final of three electrical inspections can be made. The Bureau is also cooperating in



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**(NAVAL AIR STATION ALAMEDA:
CLUSTER PLANNING AND PROJECT HATCHERY NORTH
Project Manager: CALSTART continued)**

installing six EV charging stations at PHA, now scheduled to be done within the next 30 days. The Navy surplus machine shop and requested testing equipment have been installed, reconditioned, or repaired, and all pieces are operational at this time.

CALSTART's Project Hatchery Alameda has been named the Alameda Business of the Year in Manufacturing by the Chamber of Commerce.

Cluster Planning

CALSTART staff developed a presentation on the benefits of facilities at the Alameda Naval Air Station for electric vehicle manufacturing (see attached). This paper will be presented at the International Electric Vehicle Symposium (EVS13) in Osaka, Japan in October of this year. It's anticipated that over 1,200 people will be attending this conference. One of the goals of the paper is to stimulate interest in the NAS as an electric vehicle and component manufacturing sight.

Negotiations continue with the Navy and the re-use authority related to use of the East/West runway as a test track. The local Naval officials have determined they have no objections to the plan put forth by CALSTART to use the runway as a test track. However, the re-use authority indicates substantial delays may result because the Navy has not processed any of the ten currently pending lease requests.

CALSTART, in coordination with the Alameda Bureau of Electricians and the City of Alameda, has developed plans for a major electric vehicle race and exposition for the Naval Air Station in the fall of 1977. The primary goal of the event would be to encourage hundreds, if not thousands of EV Industry enthusiasts to visit the race and be exposed to the potential as a sight for manufacturing.

San Francisco Chronicle

TUESDAY, JULY 23, 1996



PHOTOS BY VINCE MACCIONI/THE CHRONICLE

Zebra Motor Inc. of Novato showed off its two-seat electric sports car at the Alameda Naval Air Station

An Electrifying Conversion

Clean transportation startups hatched at Alameda air station

By Jonathan Marshall
Chronicle Economics Editor

Looking out on million-dollar views of San Francisco and the Bay, dozens of government officials, engineers and curious citizens zipped around the Alameda Naval Air Station airfield yesterday in electric cars.

The occasion was the first open house of a business incubator center housing eight small companies in the clean transportation field. These startups are pioneering the conversion of the 1,842-acre Alameda Naval Air Station to civilian uses, before the Navy finishes its pullout next April.

Located at the air station's Hangar 20, the center was opened only about six months ago with the help of a \$2.5 million federal grant from Calstart, a non-profit consortium dedicated to advancing transportation technology in California.

Already the incubator employs 50 and is three-quarters leased. An A-6 Intruder aircraft parked just outside, with its wings folded, is the only reminder that military jets were once housed in the 65,000-square-foot space.

"Just a few months ago this hangar was empty and the mood was solemn,"



Electric cars were parked next to an A-6 Intruder at the air station

said Alameda Mayor Ralph Appenzato. "Thanks to Calstart we have a hangar full of vibrant activity, full of hope and optimism."

The idea behind business incubators is to create synergies by putting small companies in the same industry side by side.

Calstart has created a similar business incubator for clean transportation companies in its hometown of Burbank. That site now has 25 businesses.

Michael Gage, president of Calstart, said both should prove viable. "Alameda can become a center and prestige address for the advanced transportation technologies industry," he said.

The U.S. Defense Department has helped fund some of the technology that was on display at yesterday's open house.

Thanks to a grant from the Defense Department, engineer Lee Ackerman, who works out of the hangar, just perfected a DC-motor controller that could slash the cost of high-performance electric vehicles. He's close to signing a sales agreement with Zebra Motor Inc. of Novato, which gave participants at the open house high-speed test drives of its snazzy, two-seat sports car.

Zebra also may relocate to the naval air station, but is considering incentive

ELECTRIC: Page C5 Col. 1

ELECTRIC: Station's Conversion

From Page C1

packages from other California cities, said Gary Starr, who helped found it along with an electric bicycle company, Zap Power Systems of Sebastopol.

Its car, which proved a hit with the crowd, will retail for about \$20,000 in full production. It's not the most practical car, Starr conceded, but it's eye-catching and peppy. You may not be able to go 400 miles in the Zebra, he said, "but you should at least have fun for 40 miles."

A more pedestrian-looking two-seater will become available this month to patrons of the Walnut Creek and Colma BART stations, thanks to Green Motorworks, a North Hollywood electric vehicle marketer that has space in the Alameda hangar.

Earlier this year, more than a dozen of its small electric cars were stationed at the Ashby BART station, where they have proven a hit with employees of Sybase and other companies that lease them for local trips. "We don't have enough cars for everyone who wants them," said William Meurer, president of Green Motorworks.

Green's cars will come with dual air bags, travel up to 60 miles per hour and have a range of about 60 miles on a battery charge when they go on sale to the general public next year for about \$15,000, Meurer said. For customers with more traditional design tastes, Meurer also had electric conversions of an Alfa Romeo Spyder and a Ford Escort station wagon on display.

With General Motors scheduled to begin selling its sporty, two-seat Impact electric car next year, these and other startup companies in Alameda hope to ride a wave of growing public interest in quiet, nonpolluting vehicles.

But Meurer conceded his firm, and the industry as a whole, needs some breakthroughs in range and cost before electric vehicles will become big sellers. "We cannot provide a replacement for the gas car right now," he said.

The Oakland Tribune.

Tuesday
July 23, 1996



LAURA A. ODA — Staff

The City Bee, a Norwegian electric commuter car, is dwarfed by a jet at Alameda Naval Air Station on Monday.

Air base gets jump start on civilian life

By Kathleen Kirkwood
STAFF WRITER

ALAMEDA — Electric-powered cars of all shapes and sizes zipped around the runways Monday at Alameda Naval Air Station, giving test drivers a taste of the future.

"Definitely, I would buy one," said Remonla Bowie, after a ride around the quiet base in a

sporty-looking electric "Tropica."

Bowie said she would trade in her Mercury Sable for the noiseless little car. The deciding factor came down to the cost of fuel. Charging the Tropica costs about \$1.25 for every 100 miles.

"It's exciting, easy and it's under \$20,000," said Bowie, who works for Communications

Technology Cluster of Oakland. "I want it."

Built by Zebra of Novato, the Tropica was one of two dozen "alternative-fuel" vehicles — including scooters, bicycles and even a few custom-fitted shopping carts — parked on the base's runway.

They were lined up around a Navy A-6 Intruder jet to sym-

bolize the ongoing transition of the base from military to civilian use. The base is due to close down entirely in April 1997.

The occasion was the grand opening of CALSTART's business incubator in a 65,000-square-foot hangar at the base. There are now eight firms housed

Please see **Conversion**, A-12



LAURA A. ODA — Staff

Jerry A. Martin of the California Air Resources Board takes a low-riding electric-powered bicycle for a spin along the Alameda Naval Air Station runway.

Conversion: Potential plentiful

Continued from A-11

there, with about 50 employees using surplus machine tools and equipment that's being left behind by the Navy.

"Just two years ago, this hangar was empty, the mood was solemn and there was no cause for joy and celebration," Mayor Ralph Appenzato said.

Appenzato said the CALSTART activity brings "a new sense of hope and optimism" to base conversion efforts.

About 200 people attended the event, many of them entrepreneurs whom CALSTART hopes to lure to the center, which they are calling "Project Hatchery North." CALSTART is a consortium of 200 state firms and agencies, based in Burbank.

Lon Bell, CALSTART's founder, said the goal was to bring together entrepreneurs with advanced transportation technology ideas together, and give them a jump start.

"Hatcheries work. Hatcheries spawn new industry," said Bell, who is the president of Amerigon Inc., the largest firm located at the Alameda CALSTART hub.

This month, Amerigon started shipping out electric car "kits," partly assembled at the base, for companies in Asia. Crates containing the kits for Amerigon's "EV-4" were lined up in the hangar.

Other models on hand at the base were the Norwegian-built "City-Bee" and "Citi," small commuter cars that are now being used in a BART electric car dem-

onstration program.

"The thing that's amazing about them is they are so quiet. You could drive up on someone and they wouldn't hear you coming," said Gene Keller, marketing director for the Alameda Bureau of Electricity.

Steve Skarry, owner of Island Auto Sales agreed, after test-driving the Tropica. "I can wait for them to come on the used-car lot so I can sell them."

The CALSTART hub, modeled after a cluster of 19 CALSTART firms in Burbank, could create 400 jobs by December 1996 and has the potential to employ thousands by capturing the wave of new and alternative transportation technology, according to CALSTART officials.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Project Hatchery North

CALSTART Participant: CALSTART, Alameda				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
61,666	21,431	196,668	151,777	46,666	120,346	151,777	22.83%
Totals 61,666	21,431	196,668	151,777	46,666	120,346	151,777	22.83%

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: NAS Planning Grant

CALSTART Participant: CALSTART, Alameda				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
27,778	13,623	166,668	28,623	27,778	28,623	28,623	82.83%
Totals	13,623	166,668	28,623	27,778	28,623	28,623	82.83%



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12. RUNNING CHASSIS II

Project Manager: Amerigon Incorporated

As reported in last quarter's report, this program has encountered some difficulties. Amerigon was unable to obtain financing for the Basic Electric Vehicle (BEV) until the Indian government had given approval to the program. Apparently, that approval has been secured. However, Amerigon is proposing to delay, by approximately six months, the completion of the two aluminum frame BEVs and the five BEV electric drive trains. Amerigon is also proposing that the five BEVs be completed to the running chassis phase as opposed to the complete vehicle stage (body panels included). The reason for this proposed change in statement of work is a result of an underestimation of the costs associated with the body panel construction and design processes. Amerigon believes that the most important engineering and testing work will be completed by building the cars to the running chassis phase.

A summary of Amerigon's request for a change in the payment and milestone schedules is attached. This summary was provided to DARPA Program Manager Robert Rosenfeld on September 30, 1996 during a program review at CALSTART's facility at the Alameda Naval Air Station. Mr. Rosenfeld said he would review this request and discuss it with other members of the team who had a longer history of involvement with this effort.

Proposed DARPA Contract Revision: September 28, 1986

Current Program				Proposed Modifications				Comments	
Date	Objective	ARPA \$	Match \$	Objective	DARP A \$	Match \$			
11/14/95	Initial payment	200	460	Initial Payment	200	460		None	
12/31/95	BEV Drive Train: Breadboard design EV4: Running Chassis with advanced components BEV: One steel frame	175	200	Done	175	200		None	
3/31/96	EV4 Preparation: Fabricate parts; revise design EV4 Build: Build 1 Complete car	125	0	EV4 Preparation: Same EV4 Build: Car only partially completed.	125	0		Partial delay on vehicle build. @ vehicles completed on 8/27.	
6/30/96	Vehicle Testing: Complete all testing for EV4 and BEV Aluminum BEV: Build 2 with welded chassis Tooling: Revise tools for BEV and EV4	150	20	Vehicle Testing: Completed all testing for BEV and some for EV4 Aluminum BEV: Delayed until 3/31/97 and de-scope to exclude body panels Tooling: Done	40	15		Vehicle Testing: Delayed completion of EV4 testing until 8/30. Vehicles now in final testing. Aluminum BEV: Delayed until 3/31/97 because of delay in India Venture. Chateron and Furman now in India to resolve. Have initiated detailed planning of aluminum BEV workplan. Request De-scope because body panels have low technical merit and substantial costs.	
9/30/96	Aluminum BEV: Build 2 additional with welded and bonded frames BEV Drive Train: Complete design package; build/test 5 units	50	0	Vehicle Testing: Completed remainder of testing for EV4 Aluminum BEV: Delayed until 3/31/97 and de-scope to exclude body panels. BEV Drive Train: Delayed to 3/31	70	15		Aluminum BEV: Delayed until 3/31/97 and de-scope to exclude body panels. (Same status/explanation as above.) BEV Drive Train: Delayed to 3/31 because of overall program delays. Complete design package has been released to outside contractor for completion of integration of charger electronics.	
12/31/96	Final Report: Complete	0	40	Final Report: Delay until 3/31/97 BEV Drive Train: Complete design package; build/test 5 units	20	15		Final Report: delay to match program delays. BEV Drive Train: Delayed per above.	
3/31/97	none	0	0	Aluminum BEV: Complete build and testing of 4, all w/o bodies (2 with welded frames; 2 with welded and bonded) Final Report: Complete	70	15		Completes all outstanding deliverables (assuming de-scope of body panels from aluminum vehicles)	
Total		700	720		700	720			

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: ARPA Running Chassis Program

CALSTART Participant: Amerigon				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
50,000	567,610	1,380,000	1,350,597	50,000	445,222	1,350,597	2.13%
Totals	567,610	1,380,000	1,350,597	50,000	445,222	1,350,597	2.13%



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13. Catalytic Combuster/Hybrid Electric Bus Demonstration
Project Manager: Capstone Turbine

In June, Capstone Turbine began conversations with Advanced Vehicle Systems (AVS), a bus manufacturer, to conduct a field test of the turbine in an AVS manufactured hybrid electric bus. AVS is presently participating in another DARPA funded program and believed to be in good standing with DARPA. It was determined that AVS would be a suitable partner so an agreement was made to proceed with a field test of the Capstone turbine in an AVS bus.. Capstone Turbine built a turbine for an AVS bus and they anticipate acquisition of the bus in the second week of November. Plans are in progress for timelines pertaining to the integration and test phase.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Vandenburg AFB Hybrid Bus								From: July 1, 1996	
CALSTART Participant: Capstone Turbine								To: Sept. 30, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %		
5,000		590,000	358,243	10,000	128,250	358,243	39.28%		
Totals	5,000	0	590,000	358,243	10,000	128,250	358,243	39.28%	



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14. PROGRAMMABLE DC CONTROLLER

Project Manager: Jefferson Programmed Power

This project is now complete. The programmable controller was renamed the "Jefferson Clipper" and is reported to be "equally suitable for specialized military, utility vehicle and fleet uses." Commercialization has begun with a commitment for initial units to be installed in the Zebra purpose-built sports car.

As indicated in prior quarterly reports, Jefferson Programmed Power Company had been unable to independently test its controller due to problems encountered by three separate small manufacturers of electric vehicles. Nonetheless, the program was reviewed with DARPA Program Manager Robert Rosenfeld, and it was determined that the initial thrust of the program's goals had been achieved. A copy of the final technical report has been attached in the Appendix.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: M3000DC Motor Speed Controller Dev. Program

Participant: Jefferson Programmed Power				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
0	0	434,000	439,804	0	195,300	439,804	-1.34%
Totals	0	434,000	439,804	0	195,300	439,804	-1.34%



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15. PROGRAM TO MINIMIZE LOSSES IN MECHANICAL BATTERIES FOR ELECTRIC VEHICLES

Project Manager: Avcon

This program is essentially proceeding as planned. An engineering report has been generated to identify a detailed test plan for the eddy current reduction program (see attached).

During this quarter, Avcon started developing a comprehensive test plan for the eddy current reduction program. The objectives required for analysis and testing have been completed.

Test equipment and methods have been detailed to measure the eddy current braking torque while the shaft is rotating at a constant velocity. The test fixture consists of two radial homopolar magnetic bearings levitating a test shaft which is to be constrained in four axis with active bearing control. The shaft will be driven at a constant speed with an electric motor mounted onto a reaction torque sensor. The sensor allows the output motor shaft torque to be measured directly. Since the only forces acting on the shaft, when levitated and at constant speed, are windage and eddy current braking, the windage will be calibrated out, thus allowing the braking torque to be inferred.

This project includes evaluating two different magnetic bearing designs. A baseline bearing has been selected and the second design will incorporate features currently known to reduce eddy current losses.



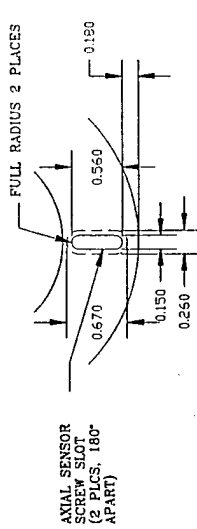
**Defense Advanced Research Projects Agency
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**(15. PROGRAM TO MINIMIZE LOSSES IN MECHANICAL
BATTERIES FOR ELECTRIC VEHICLES
Project Manager: Avcon continued)**

Testing objectives include varying the thickness of the rotor lamination and the stator lamination to determine the corresponding effect in eddy current losses. The material used in the rotor lamination will be evaluated. The geometry of the stator slot opening will be considered. And, testing will include the possibility of using a laminated spacer between the rotor sections. Testing also includes the operation of the bearing under various load conditions.

Avcon reports that some manufacturing (laminated stacks bonded and stator cores EDM machined) has been completed for this project.

Plans for the next quarter include completing the test plan and beginning the analysis required to develop the "breakthrough" bearing.



PART CASH NO.	MCXT	FINAL	FINAL	
			MCXT ASSY	USED ON
			APPLICATION	
		QTY REQD		
		PER ASSY		

NOTES: UNLESS OTHERWISE SPECIFIED

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Flywheel Magnetic Bearing Improvements

CALSTART Participant: AVCON				To: Sept. 30, 1996			From: July 1, 1996		
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %		
72,298	75,412	206,672	75,412	139,526	0	75,412	63.51%		
Totals 72,298	75,412	206,672	75,412	139,526	0	75,412	63.51%		



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16. FLYWHEEL LIFECYCLE TESTING

Project Manager: US Flywheel Systems

Initial testing of modules produced data indicating that the magnetic bearings were producing only one-fourth of their design specification force - insufficient for the flywheel to operate. As a result, the modules were disassembled, re-worked bearings were obtained and the first module is again complete for testing. The second, third and fourth modules should be completed for acceptance testing in the next quarter.

The data acquisition and control, vacuum, and cooling systems have been checked-out and are ready to begin function testing with the flywheel modules.

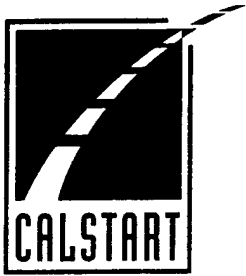
Although the bearing problem caused a delay in the program, U.S. Flywheel Systems anticipates completing the project on the schedule originally agreed.

Projected plans for next quarter include complete life-cycle testing of the first two modules.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Flywheel Program Life Cycle Testing

CALSTART Participant: US Flywheel System					To: Sept. 30, 1996			From: July 1, 1996		
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %			
10,000	489,183	1,630,000	1,813,650	105,000	195,200	1,813,650	-11.27%			
Totals	489,183	1,630,000	1,813,650	105,000	195,200	1,813,650	-11.27%			



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**17. COMPACT, RUGGED, LOW COST CIRCUIT BREAKERS
FOR ELECTRIC AND HYBRID ELECTRIC VEHICLES**

Project Manager: Coriolis Corporation

No contract has been signed yet with Coriolis Corporation. Coriolis Corporation is still seeking a manufacturing and development partner. CALSTART has made contact with officials at both Pacific Gas and Electric and Southern California Edison in hope of securing their interest in this program. Meanwhile, the Coriolis Corporation has continued to work with the Electric Power Research Institute and is finding some interest with that organization.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Compact Low Cost Power Relays

CALSTART Participant: Coriolis Corp.				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
28,572		51,144		28,572			100.00%
Totals	0	51,144	0	28,572	0	0	100.00%



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**18. ALTURDYNE ROTARY ENGINE
APU TRANSIT BUS DEMONSTRATION**

Project Manager: APS Systems

This program is progressing well and the bus should be ready within the next quarter for the Demonstration.

The Demonstration comes after two years of fabrication and assembly work that has included extensive engineering and testing. The engineering and design work is 90% completed and APS plans to create manuals and documentation of that phase. Materials, from raw material to paint have been carefully selected and attention was given to the on-board and off-board charging systems.

APS expects to gain CHP and DMV certification without difficulty and the Demonstration will be the high point of the project.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Alturdyne Rotary Engine

CALSTART Participant: APS				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
		465,000		0			100.00%
Totals	0	465,000	0	0	0	0	100.00%



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19. **SAFE ELECTROMECHANICAL BATTERIES FOR EVS**

Project Manager: Rocketdyne

CALSTART's contract with Rocketdyne was finalized in September with an agreement to begin quarterly reporting at the end of the fourth quarter, 1996. At that time, progress on the Requirements Definition and a scaled design for the containment ring will be discussed.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Safe electro Mechanical Batteries

CALSTART Participant: Rockwell								To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %				
177,000		931,000		111,500			100.00%				
Totals	0	931,000	0	111,500	0	0	100.00%				



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20. ADVANCED HYBRID RECONNAISSANCE VEHICLES

Project Managers: AeroVironment and Rod Millen Special Vehicles

This project remains on schedule.

Development of the differential is complete and the prototype production is in progress. There has been a delay in completion of the Shock Dynamometer so testing will be done in the next quarter. Millen does not anticipate that this will cause a delay in the overall program.

Modeling software and workstation were acquired at less than budget and that savings will be used in essential areas of the project.

In the next quarter, fabrication of the fully active, fully locking differential will continue as well as development and analysis of algorithms for design and system modifications.

AeroVironment continues work on the JTEV with a revised vehicle configuration that includes a smaller sized, more powerful inverter. The re-configuration actually allows more leg room as the seats are positioned further back - but, primarily it reduces engine component noise and eases access for maintenance and repairs.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Advanced Hybrid Reconnaissance Propulsion System (Suspension)

CALSTART Participant: AeroVironment				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
96,477		192,954		96,477			100.00%
Totals	0	192,954	0	96,477	0	0	100%

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Adv. Hybrid Reconnaissance Propulsion System

CALSTART Participant: Rod Millen Motorsport				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
60,287	135,582	255,861	224,463		148,570	224,463	12.27%
Totals	135,582	255,861	224,463	0	148,570	224,463	12.27%



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**21. ROTARY ENGINE AUXILIARY POWER UNIT
DEMONSTRATION**

Project Manager: Aerobotics, Inc. a division of Moller International

Moller has chosen to use a different vehicle as its primary test vehicle and has accepted delivery of the vehicle from AC Propulsion. The engine compartment has been modified to allow space for the prime mover, generator motor, generator motor controller, drive motor, drive motor controller, vacuum pump for braking assist and thermal management material. The main issues remaining are how exactly to locate the radiator for maximum elimination of engine heat and the appropriate location of the air-conditioning system.

Moller has added people to the project to meet the time lines and expects to make up for any loss of time by mid-November. Testing and reporting should be on schedule by the end of the next quarter.

COST REPORTING FORMAT **CALSTART / HEV TECH. PROGRAM**

Program: Rotapower Engine

CALSTART Participant: Moller International				To: Sept. 30, 1996		From: July 1, 1996	
Planned Period Expenditure	Actual Period Expenditure	Cumulative Planned Expenditure	Cumulative Actual Expenditure	Planned Next Period Expenditure	DOD Funds Expended To Date	Contractor Expenditures To Date	Deviation From Plan %
16,495	69,732	294,170	331,017	105,000	131,652	331,017	-12.53%
Totals	69,732	294,170	331,017	105,000	131,652	331,017	-12.53%



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22. FISCAL YEAR 1996 PROGRAMS

On September 30, 1996 CALSTART added the following programs. These projects will be included in the next quarterly DARPA report.

Modification P00007

1. Environmental Control System for Electric and Hybrid Vehicles
2. Glacier Bay / Evermont Cooperative Testing Program
3. E/HEV Manufacturability Assistance Program
4. Hybrid-Electric Prototype Truck (HEPT) Project
5. Electric Vehicle Long Range Extending Generator
6. Engineering Improvements for Purpose-Built EV
7. Propulsion System for Advanced Hybrid Reconnaissance Vehicles
8. Emergency Management System Development and Demonstration

Modification P00008

1. Quick Charging System with Flywheel Energy Storage



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Appendix

John Boesel's letter to Ms. Elaine Ely 9/25/96	A-1
John Boesel's letter to Ms. Elaine Ely 10/7/96	B-1
Jefferson Programmed Power Final Report	C-1



**Defense Advanced Research Projects Agency
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July 1 to September 30, 1996**

A-1
Letter from John Boesel to Elaine Ely dated 9/25/96



September 25, 1996

A California Non-Profit
Consortium Developing
Advanced Transportation
Technologies

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Mr. John Trotti
Santa Barbara
Metropolitan Transit District

Mr. Richard A. White
San Francisco Bay Area
Rapid Transit District

Ms. Elaine Ely
Grants Officer
Defense Advanced Research Projects Agency
3701 N. Fairfax Drive
Arlington, VA 22203-1714

Dear Elaine,

I am writing to request modifications to the statement of work to CALSTART's RA94-24 program (Cooperative Agreement MDA972-95-2-0011) related to electric and hybrid electric vehicle technology. *There will be no cost impact to DARPA as a result of these changes.* In some cases we are requesting that an existing project be restructured and in other cases we are proposing that new participants be introduced to the program. However, in all cases, the work is closely related, on a technical basis, to the original program proposed to DARPA.

**1) Optimized 30kW Turbine and Flywheel Hybrid Electric Vehicle
Project Manager: Rosen Motors/Capstone Turbine**

We are requesting that this proposal as it was originally proposed be restructured. Rosen Motors, the project leader, withdrew from the program. Their decision to withdraw from the program was based on three primary concerns: government funding may complicate their efforts; government funding would create additional accounting structures; and government funding could create issues concerning intellectual property. In short, Rosen Motors intends to invest millions of dollars into the development of their flywheel and hybrid electric vehicle and the potential problems associated with government funds outweighed their potential benefits.

However, CALSTART is proposing that development of the Capstone Turbine continue. In lieu of testing the Capstone Turbine in the Rosen Motor light-duty hybrid electric vehicle, CALSTART is proposing that the turbine be deployed in a hybrid electric bus. Capstone is also interested in developing an advanced catalytic combustor for the turbine. In this program, CALSTART and Capstone propose to collect data on a hybrid electric bus using a normal catalytic combustor and then to collect data on the same bus using an advanced catalytic combustor. If this demonstration is successful, Capstone anticipates significant demand for their technology in the 20-30' hybrid electric shuttle bus, medium-duty vehicles, and military markets. The attached proposal (Exhibit I) provides greater details on the proposed plan. The total cost of this development effort is \$600,000.





Ms. Elaine Ely
DARPA
Page 2

Capstone would provide half the funds and we are requesting that DARPA provide the other half.

2) Programmable DC Controller
Project Manager: Jefferson Programmed Power

Rosen Motors had also proposed the development of a controller and energy management system for its hybrid electric vehicles. Jefferson Programmed Power (JPP) is proposing to developing similar electronic controls for electric vehicles powered by a DC motor. Using a 32 bit microprocessor, JPP hopes to develop a prototype controller that would significantly improve the performance and lower the cost of DC drive trains for electric vehicles. A copy of the detailed proposal has been attached as Exhibit II. The total cost of this development effort is \$434,000. JPP proposes to match DARPA funds on a 1:1 basis.

3) Distributed Energy Management System
Project Manager: Delco Electronics

Delco Electronics (formerly known as Hughes Electronics or Hughes Power Control Systems) is proposing the development of a Distributed Energy Management System (DEMS). The DEMS is an integral element of the Energy Management Controller (EMC) that Delco Electronics is already developing under the current CALSTART/DARPA program. The DEMS will allow for more efficient management of the batteries. Specifically, this project proposes to develop, test, and demonstrate an effective system integrated battery energy management system capable of controlling multiple battery pack strings predominant in the designs of heavy-duty vehicles. Deliverables are to include: development and fabrication of prototype DEMS hardware with multiple pack control capability and on-vehicle hardware/software integration, verification, and testing through field demonstration and evaluation. A detailed proposal, schedule, and budget has been attached as (Exhibit 3).

The total budget for this project is \$1,113,800, of which Delco Electronics would provide \$500,000. The remaining \$500,000 is requested from DARPA. In prior conversations, you have given a verbal approval for this project. Of the \$500,000 in DARPA funds, \$250,000 would be allocated from the RA94-24 program and \$250,000 would be allocated from FY96 funds.





Ms. Elaine Ely
DARPA
Page 3

4) Internet Site Development and Demonstration
Project Manager: CALSTART

As an integral aspect of CALSTART's management of the electric and hybrid electric vehicle technologies, CALSTART is proposing to further develop and advance its Internet site. The CALSTART Internet site can serve as a central information hub for the electric and hybrid electric vehicle industry. CALSTART intends to post a significant amount of quality information on the site on a daily basis. The information would be both commercial and technical in nature. A primary function of the site would be to link existing and future DARPA funded electric and hybrid electric vehicle technology programs to other businesses and organizations around the world. The site will be accessible to and promoted to technology developers, academic researchers, national laboratory scientists, military officials, and others who are interested in electric and hybrid electric vehicle technologies as well as other advanced transportation technologies. CALSTART is seeking \$90,000 in DARPA funds to further develop and advance its Internet Site.

**5) Heavy-Duty Hybrid Electric Drive Trucks &
Electric Airport Shuttle Buses**
Project Manager: Santa Barbara Air Pollution Control District

The 5-ton truck and electric airport shuttle bus programs have been delayed indefinitely. The FMC Corporation chose to withdraw from the commercial electric drive train market for business reasons. The FMC high powered electric drive train was to have been deployed in those vehicles. Therefore, the primary purpose behind the 5-ton truck demonstration and the electric airport shuttles buses has disappeared. The SBAPCD does wish to continue with the development of the hybrid electric refuse truck with a substitute electric drive train. That program will be discussed with DARPA Program Manager Robert Rosenfeld during his site visit next week. All of the above development were referred to in CALSTART's quarterly reports.

6) Running Chassis for Commercial Uses
Running Chassis for Military Uses
Project Manager: Amerigon

Since a considerable period of time elapsed between the submittal of these proposals and the signing of the contract between DARPA and CALSTART, all the stakeholders in these two projects had the opportunity to review their plans and goals. After considerable discussion among all parties, it was agreed that the





Ms. Elaine Ely
DARPA
Page 4

two programs should be merged into a single program entitled "Running Chassis II." The primary differences between the consolidated program and the other two is as follows:

- No build of an aluminum chassis for the military.
- No crash test of an aluminum running chassis.
- An advanced aluminum chassis with body panels and interior will be built
- Five Basic Electric Vehicles (BEVs) will be built.
- Five BEVs will feature 3 different chassis types: steel, welded aluminum, welded and bonded aluminum.
- Five Productionized prototypes of a low-cost electric drive train will be built.

This revised program is designed to have greater relevance in today's marketplace. It also recognizes that the aluminum chassis is not an appropriate concept for the types of advanced scout vehicles that the military is contemplating. A detailed proposal of the Amerigon plan has been attached (see Exhibit 4).

I've attached a table (Exhibit 5) to summarize the changes to the CALSTART RA94-24 program. We believe these recommended changes are in keeping with the original mission of this program. These modifications are closely linked to the original programs or represent logical continuations of those programs. If you have any questions or need additional information, please contact me.

Sincerely,


John Boesel
Executive Vice President

cc: Mr. John Gully, DARPA Program Manager (with Exhibits)
Mr. Robert Rosenfeld, DARPA Program Manager (with Exhibits)

Attachments





Cooperative Agreement MDA972-95-2-0011

Recommended Modifications

September 25, 1996

Exhibit 1



Jun 23, 1995 07:23AM FROM NoMac ENERGY SYSTEMS

TO 915104525424

P.01

FAX FROM

Paul Kylo
NoMac Energy Systems, Inc.
655 Deep Valley Drive, Suite 205
Rolling Hills Estates, CA 90274

TEL: (310) 541-2528

FAX: (310) 541-2534

IF FAX IS MISSING PAGES OR UNCLEAR, CALL (310) 541-2528

DATE: 23 June 1995
TO: John Boesel
COMPANY: CALSTART

PHONE: (510) 452-5422
FAX: (510) 452-5424
PAGES: 5 (INCL. THIS PAGE)

Below is NOMAC's concept for the Vandenberg AFB Hybrid-Bus Project that we spoke of last week in our meeting. Please call me if you have any questions.

1.0 PROJECT SUMMARY

Capstone Turbine Corporation

NoMac Energy Systems, Inc. proposes to demonstrate the viability of a hybrid passenger bus concept utilizing a NOMAC 24 kW gas turbine-driven generator set. The turbogenerator will be integrated into one of the hybrid buses at Vandenberg Air Force Base and will replace the existing reciprocating engine-driven auxiliary power unit (APU).

Specifically, this project has been developed with consideration given towards the following goals:

1. Prove the turbogenerator as a viable APU technology for hybrid transit vehicles;
2. Obtain a performance comparison between a hybrid vehicle powered by a gas turbine driven APU and a reciprocating engine driven APU;
3. Reduce the tailpipe emissions of the bus through the development of a catalytic combustor.

Capstone

The program will be conducted under the direction of NOMAC. APS Systems, the systems integrator for the existing buses, will be consulted during the design phase and will have the authority to approve all interface work to ensure compatibility with existing on-board systems.

Capstone

The project will last approximately one year after initiated. At the completion of the project, NoMac will deliver a final report to all program participants that will analyze the performance of the turbogenerator in actual vehicle drive cycles.

Jun 23, 1995 07:23AM FROM NoMac ENERGY SYSTEMS

TO 515104525424

P.02

2.0 TECHNICAL ISSUES

Turbogenerator

NOMAC has developed a compact, lightweight, 24 kW gas turbine-driven generator set designed to operate as the heat-engine in hybrid electric vehicles. It utilizes a 96,000 rpm shaft-speed generator that is fully integrated with the compressor and turbine wheels. This single rotating shaft is supported on self-pumping air bearings; thus, no lubrication system is required. A unique circumferential recuperator is used to increase the peak operating efficiency from 14% without the recuperator to 30% with the recuperator while maintaining a very compact package.

To date, several engines have been built and rig tested. More than 20,000 start and stop cycles have been performed on the air bearings and over 300 operating hours have been logged on test engines. The integration of the turbogenerator into the bus will enhance the test program by quantifying generator set operating data during actual duty cycles.

Vandenburg Bus

A fleet of buses are used at Vandenburg Air Force Base to shuttle personnel about the base. The majority of these buses are powered by typical diesel engines; however, several of these buses have recently been converted into hybrid electric buses by APS Systems of Oxnard California.

These hybrids use a 30 kW natural gas fueled reciprocating engine to act as a battery charger. This increases the daily range of the bus while taking advantage of the zero emission aspect of an all electric vehicle.

The current operating scenario is for the reciprocating engine to be commanded on as the batteries drop below a fixed state-of-charge. The engine then remains on until the batteries are charged back to their full-charge level.

Vehicle Integration

The integration task consists of two functions. First, a mounting configuration will be designed to install the turbogenerator in the vehicle's existing engine compartment. The mounting approach will be based on existing analyses of the various shock and vibration loads that will be seen by the turbogenerator in an on-road application. Separate exhaust and intake ducts will be routed through the engine compartment to provide the appropriate airflow.

Jun 23, 1995 07:24AM FROM NoMac ENERGY SYSTEMS

TO 915104525424

P.03

Second, a complete design review of the vehicle's control system will be conducted with engineering personnel at APS Systems. An electronics interface will then be developed that will provide the communication link between the generator set inverter and the existing controller.

Catalytic Combustor Development

Initially, the turbogenerator installed on the bus will be outfitted with a conventional natural gas combustor. As part of this program, the development of a liquid-fueled, near zero-emission catalytic combustor will be completed.

Capstone
The design of the catalytic combustor will be the result of a conceptual design study completed by NoMAC under contract to the Southwest Research Institute. This program is currently in the final reporting stages. At its conclusion, a go forward plan will be introduced to take the catalytic combustor through prototype production, simulated bench testing and turbogenerator integration.

Vehicle Demonstration

Upon completion of the turbogenerator integration, the system will then be debugged and prepared for road testing. Performance of the bus and the turbogenerator will be monitored during actual duty cycles at Vandenburg AFB.

As stated above, the initial configuration of the turbogenerator will be with the conventional combustor. This will provide a baseline approach for emission characterization. After a period of data collection, the conventional combustor will be replaced with a near zero-emission catalytic combustor. An equivalent amount of data will be monitored to compare engine performance and tailpipe emission data.

The performance characteristics will then be evaluated and final documentation provided to the project participants.

3.0 COMMERCIALIZATION ISSUES

Capstone
NoMAC has identified a need for small gas turbine-driven generator sets in both vehicular and stationary applications. The long-term goal is to produce generator sets in quantities of tens or hundreds of thousands of units per year for hybrid electric automobiles. The turbogenerator will provide electric autos with the equivalent range of conventional autos along with amenities such as air conditioning and heating combined with dramatic improvements in performance, energy efficiency and emissions. However, the cost targets to enter this market are formidable as the hybrid power train will have to compete economically with a conventional power train.

Jun 23, 1995 07:25AM FROM NoMac ENERGY SYSTEMS

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P.04

Initially, NoMac's marketing efforts will be concentrated on stationary power and hybrid transit bus applications that can command a higher installed cost than the automotive market. These markets require an acceptable level of reliability, noise, emissions and maintainability.

NoMac has recently hired two separate marketing consultants to conduct independent studies on potential stationary power and transit related markets for the 24 kW turbogenerator. The major findings of these studies indicate that there is a strong interest for a low cost, low polluting electrical power source in the 24 kW frame size. Its primary use would be in facilities with high electrical loads and in the 20 to 30 foot class of transit buses. Other interested markets include mobile power sources for custom coaches, refrigerated trailers and ground power units.

4.0 PROJECT SCHEDULE

The project schedule is included following this document. It is anticipated that the project will last approximately one year from initiation.

5.0 COST SHARING

The project budget is shown on a task basis in Table 1 below. The total cost for the project is estimated at \$600,000. This includes all system engineering for complete integration of a NoMac 24 kW turbogenerator into one of the existing buses at Vandenberg AFB, final development of the catalytic combustor, demonstration of vehicle under actual duty cycles and presentation of findings.

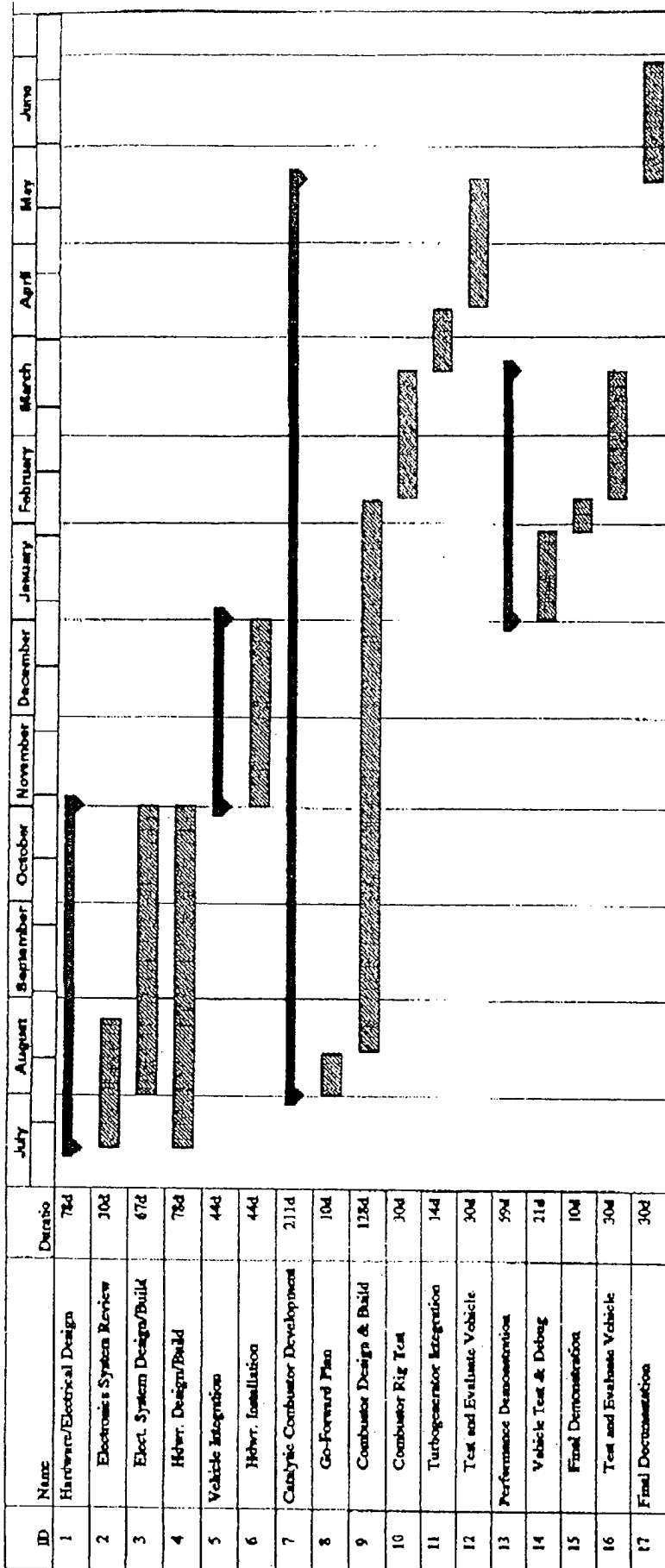
Table 1
Budget: Vandenberg Hybrid Project

Project Task	CALSTART Payment	NoMac Match (Cash)
Hardware/Electrical Design	\$ 40,000	\$ 40,000
Vehicle Integration	\$ 90,000	\$ 90,000
Catalytic Combustor Development	\$150,000	\$150,000
Performance Demonstration	\$ 20,000	\$ 20,000
Total	\$300,000	\$300,000

Jun 23, 1995 07:26AM FROM NOLAN ENERGY SYSTEMS

TO 9104525424

P.05



Project: Vandenberg Hybrid Bus Program
 Date: 6/22/95

Critical
 Noncritical

Progress
 Milestone

Summary
 Rolled Up

EXHIBIT B

BUDGET/SCHEDULE/MILESTONES

VANDENBURG AFB HYBRID BUS PROJECT

CAPSTONE TURBINE CORPORATION

QUARTER	TASK	DESCRIPTION OF MILESTONES	CAPSTONE MATCH	CALSTART	TOTAL
09/30/95	TASK 1	Award. Complete Catalytic Pre Burner, Fuel Injector, and Combustor Designs. Hybrid Bus Installation Activities, Catalytic Combustor Development	\$40,000.00	\$40,000.00	\$80,000.00
12/30/95	TASK 2	Rig Test Catalytic Element. Demo Catalytic Pre-Burner and Combustor. Complete Systems Integration Complete Genset Build	\$102,500.00	\$102,500.00	\$205,000.00
03/30/96	TASK 3	Complete existing System Removal. Complete System Design. Complete Vehicle Mods - Mechanical & Systems. Release Genset Installation Design. Complete Genset System Installation Complete Installation Checkout. Complete Emissions Testing Phase I.	\$105,000.00	\$105,000.00	\$210,000.00
06/30/96	TASK 4	Complete Combustor Testing/Optimization, Emissions Testing. Retrofit Combustor	\$45,000.00	\$45,000.00	\$90,000.00
09/30/96	TASK 5	Complete Test Report.	\$2,500.00	\$2,500.00	\$5,000.00
12/30/96	TASK 6	Complete Road Test Bus, Complete Final Performance Report.	\$5,000.00	\$5,000.00	\$10,000.00
		TOTAL	\$300,000.00	\$300,000.00	\$600,000.00

The initial invoice is required to have a Management Plan included at the time of submission. The Management Plan must include milestone events and expenditure schedules that will enable CALSTART to monitor progress on an ongoing basis. Quarterly reports are required with each quarterly invoice.

CALSTART'S general policy is to withhold 10% of the total funding, pending approval of the final report, government audit or contract closure.



Cooperative Agreement MDA972-95-2-0011

Recommended Modifications

September 25, 1996

Exhibit 2



Jefferson Programmed Power

M300 SERIES D.C. MOTOR SPEED CONTROLLER PRODUCT DESCRIPTION

By Lee Ackerson
May 5, 1995

INTRODUCTION

The fledgling electric automobile industry is at a crisis point. Although government agencies are mandating the sale of zero emission vehicles and auto makers have demonstrated some concept and limited production vehicles, American industry has not supplied a cost effective motor controller which manages the energy, safety and control functions that will allow the electric vehicle succeed.

The era of electric transportation may stand or fall with the technological advances made in battery technology and motor controller/drive innovations. But low cost, high technology vehicle controller development is at a standstill. **The single major U.S. supplier of series D.C. motor controllers, Curtis\PMC, has not addressed the needs of the electric vehicle industry.**

Though Curtis has a 120 volt 400 amp controller and has recently released their 144 volt/500 amp controller, there are several important reasons why Curtis may not meet the future needs of the electric automobile industry:

- * Curtis\PMC has reportedly withdrawn its support of OEM/dealer conversions of its regenerative controller. Regenerative braking is nearly a necessity for automobiles or controls sold into the European Economic Community and very significant energy saving feature needed in lead acid powered automobiles.
- * Curtis is a manufacturer of mobility aids, golf cart controllers, forklift controllers and other high volume products and as such has business interests other than on-road vehicle controllers.
- * All Curtis\PMC's on-road controllers are analog based and lack the capability to perform many of the critical functions needed for fully functional vehicle controllers.

Jefferson Programmed Power is designing controllers specifically for the OEM manufacturer of electric vehicles. Vital to the success of the OEMs are low cost products for high volume production and highly reliable controllers with the appropriate application of high technology. The development strategy has six important elements:

1. Define the current and voltage ranges that the OEMs need to make their products successful. Work with them to help carefully analyze the factors that affect the performance and operation of the vehicle. This is an *extremely important function* that is rarely, if ever, done by motor speed controller manufacturers.
2. Design the controller for high volume production.
3. Work with the motor manufacturer to characterize the performance of the motors and ensure that the controller algorithms protect the motor as well as internal components.
4. Use of industry standard "C" and "C++" compilers, modular software, good software engineering techniques and a rigorous program of software testing will be an absolute necessity for reliability of the product.
5. Design for manufacturing test. A significant cost of a complex product can be spent on manufacturing test processes if the design doesn't lend itself to mass production and fast cycle testing.
6. Rapid development schedule using sound engineering principles and use of engineering tools to leverage development resources. The extensive use of CAD software for mechanical, simulation, design, and PCB layout allows for an accelerated development pace.

DESCRIPTION OF CONTROLLER SYSTEMS

The first product in a family of motor speed controllers from Jefferson Programmed Power is the M300 controller. Its most important features are:

- | | |
|---|-------------------------------------|
| * 144 volt | * Dual motor control |
| * Regenerative and plug braking | * Built-in optional battery charger |
| * 750 Amp peak current limit | * 32 bit microprocessor control |
| * 24-32 OEM definable I/O lines | * Programmable parameters |
| * Fully enclosed components in a single package(including contactors) | |

MECHANICAL Prototype and initial production controllers will have thin walled aluminum "clam shell" casting covers over the heat sink plate base. One version of the controller will contain all contactors for regenerative braking, plug braking, and electrical reversing operation. Electrical signal connections by the OEM will be with splash-proof circular connectors and power connections to the battery pack and motors will be from copper bus bars.

Estimated weight of controller	26 lbs.
Length of controller	17.50"
Width	10.75"
Height	4.50"

COOLING Passive cooling with the heatsink attached to a firewall, conductive surface (TBD), or aluminum extrusion. An optional forced air cooling system with closed loop control of temperature by the main computer attaches to the same mounting connections as the passive system. For severe environments and conditions, a small heat exchanger could be accommodated with closed loop control of coolant pumping.

ELECTRICAL POWER CONNECTIONS The battery pack voltage range is a programmable function. Operation from 72 volts to 144 volts is the specified range. However, the low cost of lower voltage power components makes the under 100 volt controller a different assembly.

SIGNAL INPUTS AND OUTPUTS

- * 5K to 0 throttle input
- * Brake pot input 5K to 0 input
- * Vehicle controller disable input
- * RS232/485 channel for on-vehicle use
- * Brake inputs (2)
- * 16 general purpose inputs(digital)
- * 2 I/O high speed timer inputs
- * Isolated throttle (inductive/capacitive)
- * Encoded direction signal inputs(3)
- * Emergency Kill input (hard wired)
- * RS232 diagnostic port input
- * 8 medium current outputs
- * 2 general purpose analog inputs

PROGRAMMABLE OPTIONS

- * Neutral power-up needed for operation
- * Battery Pack voltage programmable
- * Set active polarity of input signals
- * Acceleration rates
- * Battery charger options
- * Mapping of throttle and braking pot inputs for responsiveness
- * Zero throttle power-up for operation
- * Enable/disable input signals selectively
- * Current limit settings
- * Maximum speed setting
- * User interface options

CONTROLLER OPERATING MODES

DRIVE MODE When encoded speed switch inputs are used by the OEM, the controller operates as an electronically controlled transmission with individually programmable speed limits and torque(current) limits at each speed setting. The switching of contactors to select the vehicle direction is managed by the controller's computer. All contactor operations are "arcless" (zero current switching) to eliminate welded and short lived contacts. Throttle responsiveness, temperature compensated current limits, turbo or passing gear current limits, anti-rollback control and electronically controlled braking are selected and scaled parameters by the OEMS.

ELECTRONIC BRAKING Vehicles with no manual or hydraulic transmission will use the speed inputs and the electronic transmission of the M300 controller. The direction and main contactors in the controller can be used to control regenerative braking.

There are two types of regenerative braking: simulated compression braking and pedal braking. Electronic compression braking mimics the braking that occurs in a internal combustion powered vehicle when the foot is taken off the accelerator.

A programmable regenerative pedal braking parameter determines the maximum braking current which will occur when the brake pedal is depressed. Smooth variable braking from zero regenerative braking current to maximum is controlled from the brake pedal input with a granularity of not less than 1 part in 512.

Plug braking is the default braking mode when the regenerative brake is either not installed or is disabled. Plug braking can occur in two different modes:

1. When the vehicle's direction selector (switch inputs) is opposite to that of the motion of the vehicle.
2. Brake pedal response

The controller has programmable plug braking current limits which clamp the maximum torque applied to the armature. Also, while in plug braking mode, the accelerator or brake inputs will throttle the plug braking current from minimum current to maximum current, giving the range of a very smooth to a very abrupt braking response.

In the event that the batteries are fully charged, regenerative braking will cease and a seamless transition to plug braking will occur. Closed loop control of the plug braking diodes' temperature ensures that excessive current does not cause overheating of the assembly.

RUNTIME, REALTIME AND POWER-UP DIAGNOSTICS At power-up contactors, PWM drive and all key control circuits are disabled. After ROM, RAM, CHECKSUM, and functional diagnostics are successfully completed, the microcomputer can enable inputs, outputs and respond to commands.

While the controller is operational or in idle mode, the runtime diagnostics software checks for abnormal conditions. Realtime diagnostics will be available for performance characterization, calibration and fault detection through an alternate communications channel not available to the end user.

FAULT DETECTION A comprehensive series of software algorithms, techniques, and hardware circuits will monitor the state of the controller. The software watchdog timer is backed up by a redundant hardware watchdog time-out circuit which prohibits operation of the vehicle in the event that the software fails to

operate correctly. There are redundant methods of disabling the operation of the controller when external faults occur.

CHARGER OPERATION The initial built-in battery charger will be designed to be a convenience device which takes 115VAC input and charges the battery pack at a programmable rate. The user settings could allow charging from 15 Amp, 20 Amp or 30 Amp circuits. The charger will use the computer to control the charge rate and monitor the applied power. By monitoring the battery temperature and developing efficient charging algorithms, we believe that we can deliver a built-in charger with less than 1% THD and greater than 85% efficiency.

The computer will monitor the charge and discharge power of the controller and store interim and long term data in non-volatile memory. The data are then available for:

- ♦ Calculation of battery capacity in terms of minutes to a pre-determined state of discharge, miles or kilometers to end of charge, KW Hours of power, depth of charge etc.
- ♦ Histogram of battery performance
- ♦ Battery life estimates (monitoring of battery under extreme load is a better indication of battery capacity than voltage alone)

There may be selectable charging profiles depending upon the battery type installed. If the demand is there from the OEM, a power factor corrected input section which could accept 220VAC or 230 3 phase inputs could be an option.

AGENCY APPROVALS The design of the power electronics uses IEC and UL guidelines for high voltage and power devices (creepage, clearance, accessibility, and susceptibility to failures). We expect to ultimately get U.L. and IEC approvals for radiated emissions and safety.

SUMMARY

One of the easiest tasks in creating a series D.C. motor controller is controlling the motor's speed and current. The design for safety, ease of use, manufacturability, and applicability to the task at a low cost is significantly more complex than controlling the motor rotation. **Yet, these "ancillary" features are absolutely essential for quality products needed by the electric vehicle industry to develop and compete in world wide automotive markets.** To our knowledge, no other U.S. company is creating controllers which provide what is needed to support electric automobile industry.

Jefferson Programmed Power is dedicated solely to the task of designing and manufacturing controllers to meet present and the future needs of the electric automobile industry. We will be working with other manufacturers, government agencies, trade organizations, and fellow members of CALSTART to define, design and manufacture products the electric automobile industry needs to succeed and prosper.

DARPA
Contract
W/ CALSTART

M300 DEVELOPMENT PROJECT STATEMENT OF WORK September 6, 1995

Jefferson Programmed Power will design and develop for commercial use the M300 D.C. motor speed controller for electric vehicles. The ten month development cycle for the M300 controller will culminate in the creation of pre-production motor speed controllers that will be available to electric vehicle manufacturers for use in their demonstration and production vehicles. By pre-production units we mean controllers that have sufficient documentation for manufacturing to produce the product in small numbers (50-100 per month).

- The M300 controller will have the following features:
- All components of the controller are in one cast aluminum enclosure
- Controller may operate as a single motor or dual motor controller
- Supports regenerative braking (braking energy charges batteries)
- Supports plug braking (braking energy dissipated as heat)
- Integral battery charger
- Programmable functions and features
- 144 Volt and 750 Amp operation
- M300 controller tested and evaluated in an on-road vehicle

Program manager: Lee Ackerson
General Manager
Jefferson Programmed Power LLC

Address: 118 La Sonoma Way
Alamo, CA 94507
Tel. (510) 837-7835
FAX (510) 837-8546

M300 DEVELOPMENT PROJECT

M300 D.C. Motor Speed Controller Development Deliverables to CALSTART and ARPA

September 6, 1995

FIRST QUARTER

The first three months of development after the initial ARPA funding will be devoted to creating hardware to facilitate the development of motor control software. The low power tester will allow the logic board (the D.C. motor speed controller computer) to exercise the control software in the engineering lab. The low power test emulates a on-road vehicle on a smaller scale. There is a small D.C. series motor driven by the electronics and software at about 1/100 of the power of an electric vehicle. Most basic functions and interfaces of an electric vehicle can be tested on the bench with test equipment attached.

FIRST QUARTER DELIVERABLES

HARDWARE

1. Logic board schematic
2. Logic board PC layout
3. Fabricated stuffed and tested logic board PCB REV A
4. Filter Board schematic
5. Filter board PCB layout

SOFTWARE

1. Software test routine for RAM memory, throttle test, switch input test
2. Test software for CPU I/O functions
3. A/D conversion test SW

TEST

1. Low power test bed complete

SECOND QUARTER

The second three month period of development will focus on completion of the high power stationary tester and exercising the high power functions of the M300 controller. The high power tester allows full power testing of current limits, maximum motor speeds, regenerative braking, plug braking and thermal tests.

By the end of six months of development the M300 controller will be operating at full power on the high power tester. Ninety percent of the kernel operating code will be complete. A full power version of the controller will be coupled to the high power tester and the following items will be tested and qualified :

- Regen/Field current sensor
- Armature current sensors
- Plug and regen detect circuits
- Heat sink sensing and temperature control algorithms
- Throttle inputs
-

SECOND QUARTER DELIVERABLES

HARDWARE

1. Second logic PCB stuffed and tested (REV A)
2. Filter PCB fabricated and stuffed
3. Power electronics board PCB layout
4. Power electronics board fabricated, stuffed and preliminary tests
5. First full powered controller assembled and tested.

SOFTWARE

1. 'C' language code operating low power test bed motors
2. 'C' language routines to process throttle, switch inputs, plug braking, and rudimentary fault processing
3. RS232 Communications software to set programmable functions
4. Minimum set of programmable functions done

TEST

1. High power tester assembled and tested
2. Current sensors test fixture complete
3. Stationary high power battery packs complete

THIRD QUARTER

Full vehicle testing of engineering prototypes by Jefferson Programmed Power and development partners will be 75% complete. Regenerative braking battery charging will be demonstrated. The integration of the prototype cast enclosure will complete the engineering prototype package. During the beginning of third quarter the development partners will receive their first prototypes of the M300 controller and begin their testing.

THIRD QUARTER DELIVERABLES

HARDWARE

1. Logic, filter and power board testing complete

SOFTWARE

1. Regenerative braking software tests done
2. Battery charging software
3. 80% programmable functions done
4. 80% fault processing and diagnostics done
5. Dual motor control functional

TEST

1. Controller tested in electric vehicle. Report of findings.

MECHANICAL

1. Enclosure mechanical design done and engineering prototype castings delivered

FOURTH QUARTER

At the end of the last phase of development Jefferson Programmed Power will make pre-production M300 controllers available to development partners for additional testing and/or inclusion into production vehicles.

FOURTH QUARTER DELIVERABLES

1. Reports of external vehicle testing.
2. Reports of battery energy and power management
3. Reports of programmable features and functions
4. Pre-production schematics, bills of materials, PCB film, archived software, wiring diagrams, assembly procedures, test procedures and mechanical drawings done.

M300 DEVELOPMENT PROJECT

Development Partner Donations to the M300 D.C. Motor Speed Controller Development

September 6, 1995

2 DONATED 6.5" ADVANCED D.C. MOTORS FROM RENAISSANCE CARS, INC.	\$1500.00
TESTING AND EVALUATION SERVICES FROM RENAISSANCE CARS, INC. INCLUDING DEDICATED TROPICA FOR TESTING	\$50,000.00
EVALUATION SERVICES AND CONTRIBUTION OF MECHANICAL PROTOTYPING FROM SUNTERA	\$35,000.00
TESTING AND EVALUATION FROM B.A.T. INTERNATIONAL, INC.	\$15,000.00
DONATION OF ENGINEERING CONSULTING SERVICE FROM BILL THOMAS (10 HOURS @ \$150.00/HR)	\$1500.00
DONATION OF MANAGEMENT CONSULTING SERVICES FROM MARTIN PLOTKIN, PRESIDENT OF GD CALIFORNIA (10 HOURS @ \$200.00/HR)	\$2000.00
DONATION OF DATA BASE PROGRAMMING BY SCOTT CORNELL, PRESIDENT OF EAST BAY CHAPTER OF THE ELECTRIC AUTOMOBILE ASSOCIATION [†] (200 HRS@\$50.00/HR)	\$10,000.00

[†] Title for identification purposes only.

DONATION OF MANAGEMENT CONSULTING BY ROBERT HASLER, FORMER BAY AREA COMPANY PRESIDENT (30 HOURS @ \$150.00/HR)	\$4,500.00
DONATION OF USE OF TROPICA VEHICLE AND EVALUATION OF CONTROLLER FROM THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI)	\$5000.00
DONATION OF COMMUNICATIONS AND REPORT WRITING FROM SHELLEY BUCK (200 HOURS @ \$40.00/HR)	\$8000.00
ADDITIONAL CASH CONTRIBUTION	\$3402.00
TOTAL OF ALL MATCHING CONTRIBUTIONS	\$217,000.00



Battery Automated Transportation, Inc.

September 18, 1995

Mr. Lee Ackerson
General Manager
Jefferson Programmed Power
118 La Sonoma Way
Alamo, CA 94507

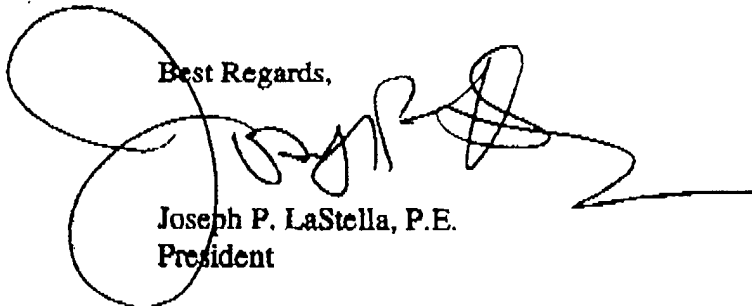
Dear Lee,

We are definitely interest in testing your M300 controller in our cars and trucks. We are willing to commit to \$15,000.00 in engineering, technician and management's time to evaluate the controller during the 10 month development program.

B.A.T. International, Inc. has development programs of its own, some of which will be coincident with your development cycle. We will make a good faith effort to do the testing and provide a short written report of our findings, but we must consider our own interests and developments first if a conflict arises and therefore reserve the right to modify our commitment to the testing of the M300 controller.

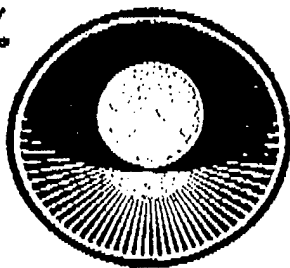
We look forward to working with you in the coming months on this and other projects.

Best Regards,



Joseph P. LaStella, P.E.
President

510 837-8546



SUNTERA
The Solar Electric Chariot Company

*Jonathan -
For non-
records - went
out today.
Chad
9-18*

September 18, 1995

Mr. Lee Ackerson
General Manager
Jefferson Programmed Power
118 La Sonoma Way
Alamo, CA 94507

Dear Lee:

We look forward to helping Jefferson Programmed Power develop the M300 vehicle controller by donating testing, evaluation, and analysis effort. We will accept prototypes of the M300 controllers and evaluate their capabilities in our pre-production vehicles here in Hawaii. We expect to provide the donated labor as follows:

<u>TASK DESCRIPTION</u>	<u>DOLLAR VALUE</u>
Mechanical engineering analysis time for form and function of controller design	\$ 5,000.00
Electrical interfaces analysis and adaptations	2,500.00
Test and evaluation time of prototype controllers	25,000.00
Management and engineering analysis, reports and feedback	2,500.00

Our testing effort will include performance analysis, power management, safety, thermal testing, and assessment of the programmable features of the controller. At the end of the testing we will provide to Jefferson Programmed Power a written report of our finding that will be at least five pages in length.

We reserve the right to modify our commitment as business requirements may dictate. We may devote more or less time to specific categories of test and may alter the commitment to suit our development and manufacturing schedule.

Best regards,


Jonathan Tennyson
President

Renaissance Cars Incorporated

John Grippo
Chief Financial Officer
2730 Kirby Avenue NE
Palm Bay FL 32905

Telephone (407)878-2228
Fax (407)876-2228

26 September 1995

Lee Ackerson
General Manager
Jefferson Programmed Power
118 La Sonoma Way
Alamo, CA 94507

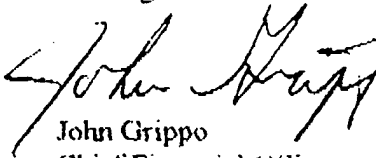
Dear Lee,

As you are already aware, we are very interested in the progress that you are making in your dual motor controller. It is our intent to thoroughly evaluate a unit just as soon as one is available.

The primary intent of our evaluation will be to determine the compatibility with our existing Tropical vehicle. In order to perform the required tests it will be necessary to dedicate a vehicle to that specific purpose. We will require your assistance to optimize the installation, both mechanically and electrically. All the test methods and results will be made available to you. We expect to modify the installation during the progress of the tests to obtain the best possible result and we assume that you will be involved in that process.

We will be responsible for all our internal costs in performing the tests. This includes the dedicated vehicle, modifications, and our engineering time. We expect you to supply the controller(s) to be tested. We anticipate that the cost of our time and materials will be in the range of \$25,000 to \$50,000. In exchange for our efforts, we would expect you to minimize any non-recurring engineering charges to us with any future orders that we may place for your controllers.

Best regards,


John Grippo
Chief Financial Officer



Cooperative Agreement MDA972-95-2-0011

Recommended Modifications

September 25, 1996

Exhibit 3



Proposal Submittal
for
Energy Management System Development and Demonstration
Project

Submitted by Delco Electronics Power Control Systems
March 8, 1996

BACKGROUND

Battery pack energy management systems have been developed and successfully integrated onto light duty vehicles' battery systems effecting improved performance and enhanced life of advanced VRLA batteries. This project is to build on this existing battery energy control technology to develop a battery energy management system application for heavy duty vehicles which contain four times the number of battery modules as light duty vehicles. Present electric heavy duty vehicle designs do not have an effective energy management system or use systems that require costly non system integrated wiring and hardware. This project is to develop, test, and demonstrate an effective system integrated battery energy management system capable of controlling multiple battery pack strings predominant in the designs of heavy duty vehicles. Deliverables are to include: development and fabrication of prototype Distributive Energy Management System hardware with multiple pack control capability and on-vehicle hardware/software integration, verification, and testing through field demonstration and evaluation.

The basis of this project's development for the heavy duty vehicle battery energy management system is the Battery Pack Monitor system technology developed by GM and Delco Electronics Power Control Systems for the GM "Impact". The Impact Battery Pack Monitor (BPM) is a core element of the inductive charger strategy, and is currently a production validated product. The experience gained by working with GM to develop and validate this product has provided an extensive base of expertise and knowledge about the requirements and technical solutions for effective battery management. The Impact Battery Pack Monitor system far exceeds any other battery energy management product currently on the market in reliability, testing, and overall performance. Additionally, Delco Electronics Power Control Systems has invested in a fully equipped charger and battery energy management system integration laboratory, and is presently involved

in developing charging systems and charge control systems (battery management systems) to be compatible with next generation batteries.

PROPOSED TECHNOLOGY DEVELOPMENT

The main technical consideration is that many factors affect the life, capacity power and energy of a battery. These affects are compounded in the case of a battery pack due to the imbalances in temperature, capacity, and resistance between the individual batteries in a pack. Battery manufacturers, such as GNB, now acknowledge the existence of these imbalances and are supportive of the development and integration of electronic energy management systems that enhance their batteries' life and performance.

Battery temperature variations affect charge acceptance, gassing voltage, and life under storage. Temperature variations across a battery pack causes batteries in the center (warmest) to be overcharged and those on the edges (coolest) to be consistently over discharged and undercharged. Effectively the battery pack is only as good as the weakest battery in the pack. And charging without a proper battery management system to compensate for these imbalances negatively effects the capacity and life of a battery.

Heavy duty electric vehicles, such as buses, contain multiple strings of parallel battery packs that charge at different rates due to these inherent imbalances between the individual modules. The Bluebird Bus incorporates the use of four battery packs, each consisting of 28 each 12V battery modules, which adds significant complexity to the issue of effective and safe energy management.

Additionally, high power charging is becoming a prevalent need by heavy duty electric vehicle operators to effect faster charge times for these larger multiple packs. The use of high power charging, at higher voltages and currents, coupled with the batteries' inherent imbalances significantly increases the risks of hydrogen gassing and degradation of battery life and capacity. An effective integrated battery energy management system benefits the use of high power charging.

To properly compensate for all the variations within a pack and between multiple packs, requires a system that monitors individual battery module temperature and voltage, and compensates for the capacity variations through charging equalization. Equalization is a method of directing and controlling charging at the individual module level, shunting current around the battery once it has reached it's full charge. In order to do this effectively an energy management system using distributive modules, which are electronics wired to individual batteries for monitoring temperature and voltage, is required. The proposed Delco Electronics Power Control Systems battery control system is called the Distributive Energy Management System (DEMS) and consists of a microprocessor programmed charge controller and distributive modules. The DEMS will measure individual battery voltage, temperature and provide equalization through the distributive modules, all centrally controlled through the DEMS Controller.

The objective of this project is to develop an energy management system that protects and enhances battery life, is easily adaptable to multiple vehicle platforms, is cost effective, and supports the effective and safe use of high power charging.

PARTICIPANTS

NAME	RESPONSIBILITY
Delco Electronics	Design, fabricate, and test
Virginia Power	Provide 25kW OCS
GNB	Provide batteries
Westinghouse	Inverter interface requirements
Bluebird	Bus Vehicle, Bus vehicle Interface, Mechanical Installation and Test

STATEMENT OF WORK

Delco Electronics Power Control Systems is to design, develop, fabricate, and integrate prototype DEMS hardware and software for the specific application of providing energy management for multiple battery pack configurations. The project work plan is a 12 month effort and is structured to conduct the development and testing in two phases. Phase 1 is the Concept development phase and focuses on the design, testing, and integration of the software for the central Controller and development of the DEMS architecture. Phase 2 is the DEMS Prototype system testing and integration phase. The primary element of this phase is to conduct system integration and verification of the DEMS hardware and software.

The Phase 1 development will define and prove a multi battery pack energy management architecture that will be upgraded to incorporate individual battery module charge control in Phase 2. This will prove out a system that is to be flexible and adaptable to many vehicle platforms with only minor software adjustments. Completing the Phase 2 Prototype DEMS testing will yield a flexible heavy duty high power charge control strategy that can be commercialized for EV industry wide applications.

The following narrative summarizes the development and demonstration milestone activities necessary to accomplish the project and are detailed in the attached Work Schedule.

PHASE 1 Concept

In phase 1 the software requirements and system architecture (Task # 3) will be defined for a heavy duty electric vehicle multiple battery pack configuration using the Bluebird transit bus as the developmental test platform. This system architecture for the multiple pack central controller, which is to be the basis for the DEMS controller software design, will be designed (Task #4), programmed, and implemented (Task #5) into existing PCS charge controller micro processor

hardware using a master/slave software configuration. Charger and battery integration bench testing of the new central controller software (Task #6), using GNB batteries, will be conducted in the integration lab. PCS will then install and integrate (Task #7) the software modified controller into an El Dorado electric transit bus, a PCS owned test bed vehicle. The charging system for this testing effort (Task #8) will be the MAGNE CHARGE 25kW Inductive Opportunity Charge System. Once the system has been fully field tested and system verified on the test bed vehicle (El Dorado bus), a design review of the software (Milestone 2) will be conducted to finalize any design modifications to the software.

The next step is to demonstrate the multi pack battery management control strategy on the Bluebird buses (Task #10). The buses will be equipped with the software modified charge controllers, one for each battery pack of which one will be the master, GNB battery packs, and 25kW inductive charge port systems. The buses will be used to collect field demonstrated charging and battery performance data (Task #11), and the data collected will be used to validate the software control strategy and system architecture in real world driving circumstances.

Concurrently, system requirements for the distributive module brassboard design and the upgraded central controller hardware for DEMS will be defined (Task #'s 12, 13, 14). The controller multi pack system architecture design will be merged into the upgraded central controller to create the DEMS multi pack controller concept (Task #'s 15, 16).

PHASE 2 Prototype

After the distributive module concept tests are completed and the design is verified, a small lot of the prototype distributive modules will be built (Task's #19, 20). The upgraded DEMS controller will be integrated with the prototype distributive modules and system level tested (Task #'s 21, 22). The equalization strategy will be tested as part of the total charging system by integrating (Task #23) the distributive modules onto battery packs in the PCS integration lab.

Test results and accomplishments of the teams effort to couple high power charging of multiple battery pack heavy duty EV's will be provided in a final project report (Task #25).

SCHEDULE

(See next page)

10	Task Name	4, 1995		Qtr 1, 1996			Qtr 2, 1996			Qtr 3, 1996			Qtr 4, 1996			Qtr 1, 1997			Qtr 2, 1997	
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	CONCEPT																			
2	Requirements Defined																			
3	Define Bus EMS Requirements																			
4	Build up concept Controller HW																			
5	Concept Controller SW Design																			
6	SW Testing and Lab Simulation																			
7	Vehicle TestBed Integration/Insta																			
8	TestBed Functional Test																			
9	SW Design review																			
10	Install Controllers/CP on Buses																			
11	Validation / Data Collection																			
12	Controller upgrade concept																			
13	Dist Module Requirements																			
14	Dist Module Concept Design																			
15	Build concept Dist Module																			
16	Lab Test Dist Module																			
17	Dist Module Design Review																			
18	PROTOTYPE																			
19	Build DEM Controller																			
20	Dist Module Prototype Fab																			
21	Test DEM Controller																			
22	Dist Modules prototype Lab Test																			
23	DEMS Lab Test																			
24	DEMS Design review																			
25	Final Report																			

9/10/96

BUDGET

The development and demonstration of the Distributive Energy Management System is planned as shown in the schedule and is estimated to require a total of \$1,138,000 funding. Delco Power Control Systems and Delco Electronics Advanced Products will provide an estimated \$638,000 in-kind contributions. ARPA matching funding requirements are estimated to be \$500,000 over the program. Attachment A delineates ARPA funding requirements and PCS contributions by quarter over the project schedule and milestones are shown in Attachment B. Other participants' contributions and funding requirements are not included in this proposal submittal.

MILESTONES

(See Attachment B)

COST SHARE

(See Attachment A)

Attachment A
Budget Schedule

Quarter	Total Quarterly Expenses	ARPA \$	Cost Share \$
1	461000	126000	335000
2	362000	139000	223000
3	263000	198000	65000
4	52000	37000	15000
Totals	1138000	500000	638000

Attachment B
Technical Milestone Schedule

Quarter	Technical Milestones
1	Requirements complete
2	Software design Review & Distributive Module Design Review
3	DEMS design review
4	Final Report



Power Control Systems
3050 West Lomita Boulevard
P.O. Box 2923
Torrance, California 90509-2923

In Reply, Refer to:
96-2D-RR084

Mr. John Boesel
CALSTART
3601 Empire Ave.
Burbank, CA 91505

July 9, 1996

Subject: Immediate funding authorization for the DEMS program

Reference: 1) DEMS Proposal dated March 18, 1996
2) Phase I funding request dated June 20, 1996

Dear Mr. Boesel

Delco Electronics Power Control Systems (DEPCS) is requesting authorization by July 12, 1996 for Phase I of the DEMS program per the above referenced proposal (copy attached). As previously coordinated with Calstart, a revised request for the Phase I and Phase II funding was submitted on June 20, 1996. To this date, only verbal authorization has been received to begin work on the DEMS project. At this time, we require formal written authorization to continue work.

Bluebird has been selected as a partner to install and test the multiple battery pack charging control architecture on buses for delivery to Georgia Rapid Transit Commission (GRTC) per the DEMS proposal. The window of opportunity to work with Bluebird and Georgia Rapid Transit Commission is closing rapidly. DEPCS requires immediate authorization to deliver, install and integrate charging and battery control hardware in buses scheduled for delivery to GRTC in August 1996. If Phase I authorization is not received immediately, Bluebird and DEPCS will not have adequate time to integrate hardware and will be unable to meet the delivery schedule promised to GRTC.

Additionally, DEPCS will have to reallocate resources currently dedicated to this project and default on plans to support the rollout of the GRTC buses. This will adversely affect relationships growing with Bluebird and GRTC, thus significantly delaying the commercialization of a multiple battery pack balancing system.

As previously submitted, tasks and funding requirements are as follows: Phase I consists of task ID numbers 2 through 13 and ID number 19 of page 5 of the above referenced proposal. The funding for this Phase I portion is \$237,000.00 from Calstart/ARPA and \$408,000.00 from DEPCS. Phase II consists of task ID numbers 14 through 17 and ID numbers 20 through 25. The funding for the Phase II portion is \$263,000.00 from Calstart/ARPA and \$230,000.00 from DEPCS. Please note that task ID numbers 1 and 18 are place holders only.

Please provide immediate authorization for Phase I of the project in order to continue work and avoid unrecoverable project delays. Should you have further questions, please contact me at the above address, by telephone (310) 517-5803, by fax (310) 517-5481 or by E-mail ReuxR@pcssmtp.hac.com.

Sincerely,

A handwritten signature in dark ink, appearing to read "Ruth Reux".

Ruth Reux
Business Representative



Cooperative Agreement MDA972-95-2-0011

Recommended Modifications

September 25, 1996

Exhibit 4



ARPA RA-94
CALSTART RUNNING CHASSIS II PROGRAM

PROPOSED CONTRACT MODIFICATION
FINAL REVISION

October 9, 1995

Prepared by:

AMERIGON INCORPORATED
404 East Huntington Drive
Monrovia, California 91016

Table 1: Proposal Changes

Original Deliverables	Revised Deliverables
1 advanced aluminum running chassis	Same
1 crashed aluminum chassis	None
1 advanced aluminum running chassis complete with body and interior	1 EV4 running chassis complete with Body and interior ¹
None	5 Basic Electric Vehicle (BEV) running chassis complete with body and interior (1 steel frame, 2 welded aluminum frames, and 2 advanced welded and bonded aluminum frames).
None	5 productionized prototypes of an integrated powertrain for the BEV, suitable for domestic manufacture and export.

¹ The commercial customer for the EV4 requires that the final vehicle styling and design remain confidential and proprietary as a condition of Amerigon's contract. Therefore, the completed EV4 vehicle can only be shown to individuals who have executed an appropriate secrecy agreement with Amerigon; it can neither be shown in public nor can pictures of it be made publicly available. A running chassis suitable for an EV4-like vehicle will be available to show the public as one of the program deliverables.

A. PROJECT SUMMARY**Redirection of ARC-4C**

This proposal represents a redirection of activities from Amerigon's original RA-94 proposal to ARPA. That proposal, entitled the ARC-4C proposal (Aluminum Running Chassis for Civilian Uses) laid out a program of work designed to advance our running chassis technology.

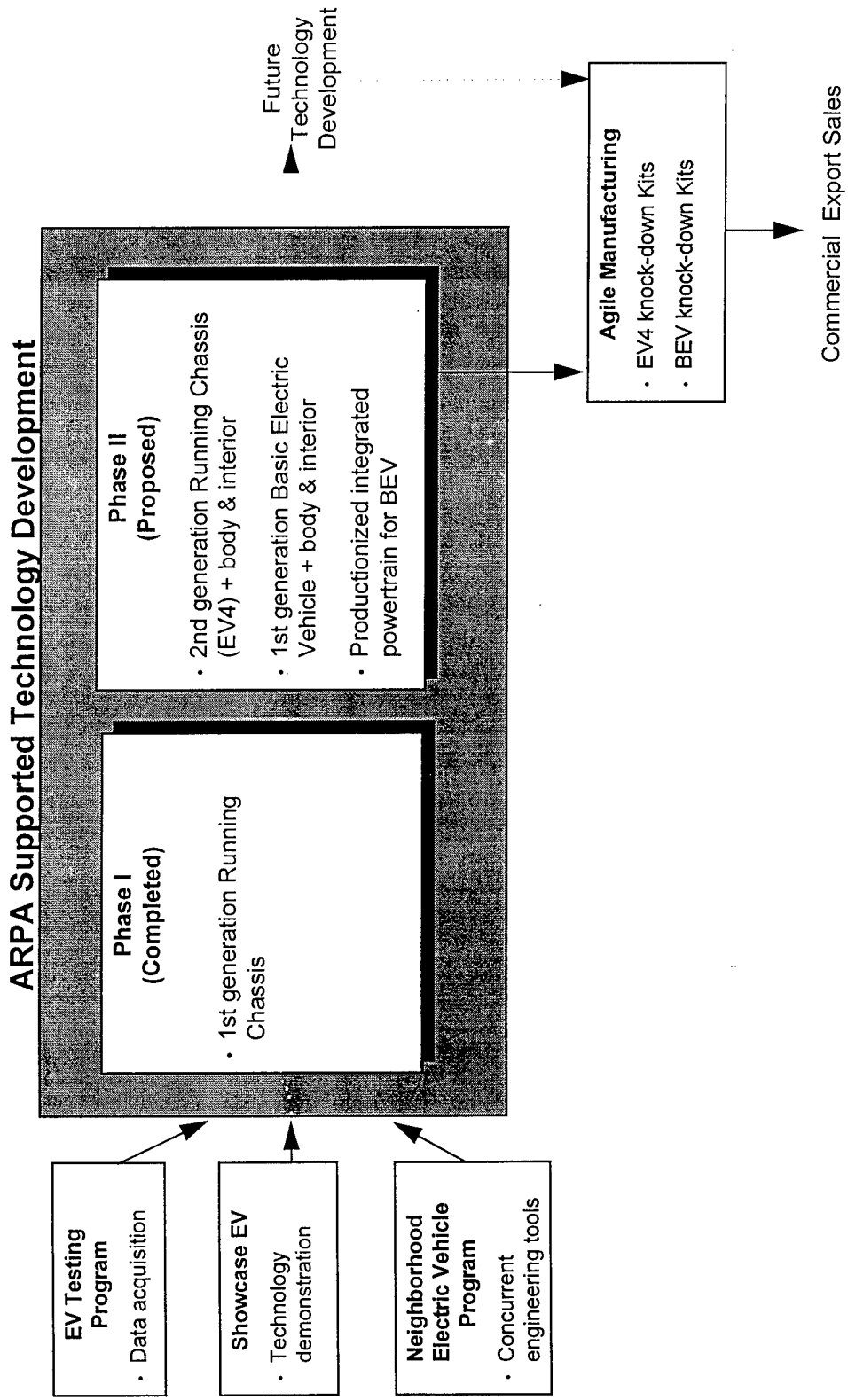
This revised proposal has the same goal of advancing the running chassis technology and achieving important innovations. However, since the ARC-4C proposal was submitted last year, Amerigon has successfully won \$9 million in orders from commercial customers for complete "wheels up" electric vehicles based on aluminum space frames. These orders are for 2 different vehicle types:

- A fourth-generation "wheels up" EV designed by Amerigon, known as the EV4, which is a 4-passenger sedan suitable for industrialized country markets; and
- A Basic Electric Vehicle, known as the BEV, which is a "wheels up" design suitable for developing markets, particularly in Asia.

Specifically, this proposal redirects our development activities towards the design and fabrication of two vehicle types sought by existing and potential customers (the EV4 and BEV described above). The project team must undertake some difficult technological challenges and achieve several important innovations and advances in order to design and fabricate these vehicles. If successful, the program is very likely to lead to follow-on commercial orders and will accelerate the commercial introduction of electric vehicles based on the aluminum running chassis concept.

The main differences between the original ARC-4C and this revised proposal are summarized below:

Figure 1: Overview of ARPA Running Chassis Program



Project Goals

CALSTART's revised Running Chassis II Program is an effort to develop and bring into production electric vehicles based on a light-weight, low cost, durable aluminum space frame construction technology. The ultimate aim of the program is to develop a new electric vehicle that can be produced for low costs at relatively low volumes.

The aluminum frame utilizes advanced aerospace technology that requires much lower capital costs than traditional auto construction techniques. This new technology also allows the production of multiple vehicle types on the same agile manufacturing line. By developing a process that requires lower capital costs and allows different vehicle types to be produced on the same manufacturing line, relatively small numbers of vehicles can be built at a low cost per vehicle. As a result, this new advance provides the breakthrough in technology needed to overcome one of the major barriers to the successful introduction of electric vehicle technology. At the same time, this new technology, if successful, also provides the light-weight and durable space frame characteristics required by electric vehicles.

To achieve this goal, Amerigon is proposing to advance the state of the Running Chassis technology for two different vehicle types. The first vehicle is a 4-passenger sedan targeted to industrialized countries, known internally as the EV4. The second is a Basic Electric Vehicle (BEV) suitable for export to developing country markets. Following are the specifications for these vehicles and the specifications for the productionized powertrain for the BEV:

Table 2: Specifications of Running Chassis II Vehicle Deliverables

Specification	EV4	BEV
Doors	2	2
Passengers	4 Adults	2 Adults & 2 Children
Wheel Base	2.48 meters (98 inches)	1.65 meters (65 inches)
Gross Vehicle Weight	4,400 lbs. (2,000Kg)	1170 lbs. (532 Kg)
Maximum Payload	1,100 lbs. (500Kg)	507 lbs (225 Kg)
Top Speed	120 kph (72mph)	65 kph (40mph)
Acceleration	0-60 kph in 16 seconds	0-30 kph in 3.2 seconds
Battery Type	lead acid	lead acid
Battery Kwh	15 kw hours	6.4 kw hours
Powertrain	3 phase 4 pole AC Induction	DC Brush (continuous-6hp/peak-17hp)
Estimated Range	60 to 90 miles	38 to 50 miles

Table 3: Specifications of the Productionized BEV Powertrain

Item	Specification
Motor	DC Brush
Horsepower	6hp - continuous 17hp - peak
Controller	Pulse width modulated
Energy Management System	Battery Monitor Intelligent charger Fuel gauge Diagnostics and warning systems
Battery Charger	110/220 Volt input 48 volt, 80 amps output
Cooling	Air
Package	Aluminum integrated
Target Selling Price	\$1000 wholesale in annual volumes of approximately 2,000.

The Benefits of Producing Vehicles Built With Aluminum Space Frames

The costs of producing vehicles based on aluminum space frame technology are lower due to the low tooling costs of this manufacturing method. The aluminum space frame is made of extruded aluminum members that can be tooled for approximately 2% of the cost of conventional stamped steel sections and panels. Assembly of the aluminum members is accomplished initially through welding and then through adhesive bonding, which requires more labor but less capital than automated welding. With these low capital costs, electric vehicles can be manufactured in low volumes (up to about 20,000 annually) at far lower costs than current vehicles using conventional methods.

Since the initial market for electric and hybrid electric vehicles will be small, this cost-effective low-volume manufacturing technique is critical. Other aspects of the program similarly lead to cost reductions. Specifically, the program is designed for multiple customers to share a single running chassis platform. This spreads development costs over a larger production base and allows economies of scale in sourcing and manufacture of components, thereby further lowering costs.

The Benefits of the Productionized BEV Powertrain

The powertrain of an electric vehicle is one of its most expensive and critical systems. It also can be one of its most expensive. In small quantities, the Hughes 50KW powertrain, for example, can cost over \$10,000, not including a battery charger and the like.

Amerigon's strategy with the BEV is to pursue an extremely low cost vehicle. This will allow initial sales volumes to be higher, thereby creating economics of scale that will further drive down costs. Lower costs then create higher volumes.

The productionized integrated powertrain for the BEV is designed for low-cost, mass manufacture. Cost savings will come from using a single micro-processor system for all functions of the controller, energy management system and battery charger. System integration design work will optimize the construction of these discrete components. A single aluminum package will house all the components for easy installation and packaging. The target wholesale selling price for the system is approximately \$1,000 on annual volumes of approximately 2,000 units.

After the five initial prototypes of productionized units are completed, they will be tested for performance and reliability. These data will be shared with ARPA, if desired.

Project Activities

The Running Chassis II Proposal is part of a broad program to resolve technical issues on aluminum space frame vehicles. The anticipated technical advances are needed for the further development of an advanced prototype vehicle for civilian and military uses. ARPA contributions are needed in addition to the other private and public funding already committed to this program.

Table 4 (below) summarizes the basic activities of the Running Chassis II Program.

Table 4: Tasks and Description of Running Chassis II Program

Task #	Name	Description
1.	Baseline testing of Running Chassis	Baseline testing of Running Chassis showing performance of existing Running Chassis prototype as measured against specification.
2.	Develop key components	Development of advanced prototypes of variable temperature seats and energy management system. (EMS). Integrate advanced EMS into powertrain.
3.	Fabricate 2nd Generation Running Chassis	Design and fabricate 2nd running chassis that is suitable for EV4-type vehicle. For cost-effective manufacture of initial commercial vehicles, welded aluminum joints will be used along with bonded joints.
4.	Plastic Body and Interior Panel Development for Space Frame Vehicles	Concurrent engineering of component and fabrication processes of panels and space frames appropriate for attachment to space frames that have near Class A fit and finish. Design and source low-volume prototype tooling.
5.	Vehicle System and Package Design	Determination of vehicle and powertrain specifications required to meet vehicle characteristics and mission profile for both EV4 and BEV. Vehicle packaging and system integration.
6.	Attachment of Body, Interior and Frame	Design of low-cost, reliable methods for attaching body and interior panels and seals to vehicle space frame.
7.	Productionized powertrain system design for BEV.	Design and build initial prototypes for low-cost integrated motor, controller, energy management system and battery chargers for the BEV.
8.	Vehicle Design Validation (DV) Build and Test	Build five BEVs and one EV4 ²
9.	Design and tooling revision	Modify design and system integration (as needed). Modify low-volume tooling (as needed).
10.	Commercialization Activities	Development of strategic partnerships. Sales and marketing for commercial development.

² The commercial customer for the EV4 requires that the final vehicle styling and design remain confidential and proprietary as a condition of Amerigon's contract. Therefore, the completed EV4 vehicle can only be shown to individuals who have executed an appropriate secrecy agreement with Amerigon; it can neither be shown in public nor can pictures of it be made publicly available. A running chassis suitable for an EV4-like vehicle will be available to show the public as one of the program deliverables.

Compliance with ARPA Project Selection Methodology

The proposed project involves both advanced technology and manufacturing processes. This program will deliver the following technical innovations and advancements:

Table 5: Technical Innovations and Advances

Task #	Name	Technical Innovations and Advances
1	Baseline testing of Running Chassis	• Create important baseline measures of performance in initial and subsequent prototypes.
2	Develop Key Components	• Development of advanced prototypes of power systems, climate control seats and energy management systems.
3	Fabricate 2nd Generation Running Chassis	• Development of low-cost and repeatable methods of assembling extruded aluminum running chassis using both welded and bonded joints suitable for cost-effective low-volume manufacture.
4	Plastic Body and Interior Panel Development for Space Frame Vehicles	• Concurrent engineering methods for subsystems complex vehicle structures. • Design of low cost recyclable panels with near Class A finish that eliminate the need for painting.
5	Vehicle System and Package Design	• Accurate modeling of plastic panel/space frame vehicle performance. • Concurrent engineering methods for integrating complex vehicle subsystems.
6	Attachment of Body, Interior and Frame	• Low stress, leak-proof attachment of panels to frame members, that exhibit low vibration & noise. • Low cost attachment and joint designs that forgive tolerance stackup and thermal expansion mismatches.
7	Productionized powertrain system design for BEV.	• Integration of micro-processing and control functions from a battery monitor, battery charger and energy management system. • Design of low-cost package for high-quality manufacture in initial low-volumes.
8	Vehicle Design Validation (DV) build and test	• Verification of technical advances in body panels, vehicle design, assembly and system integration • Quantitative measures of performance gains achievable in EVs with plastic panel/space frame/EMS systems. • Durability, stability, and environmental capability measures of such vehicles.
9	Design and tooling revision	• Solutions to defects associated with state-of-the-art design, joining and attachment processes.
10	Commercialization Activities	• Assess and subsequently improve commercial acceptance of low cost agile manufacture technology.

The project team is led by individuals each with over 30 years experience in supplying high quality automotive components and sub-systems. Furthermore, there is a realistic business plan to commercialize the technologies, thereby increasing the chances of ultimate success.

The following table summarizes how the proposed effort meets the Project Selection Methodology as identified in the RFP:

Table 6: Compliance with ARPA Project Selection Methodology

ARPA REVIEW CRITERIA	PROPOSED ACTIVITIES
Candidate Technology: Other Advanced Technology • "Technology breakthroughs are sought in any area that would significantly advance the viability of military and commercial EVs and HEVs"	Development of aluminum extrusion space frame advances the viability of EVs and HEVs because: • Reduced weight from use of aluminum relative to steel vehicle structures increases vehicle driving range. • CALSTART's RC design offers reduced tooling costs (approximately 2% of costs of traditional stamped and welded steel) lower production cost. • Easy "morphing" of frame design allows multiple vehicle types to be built from same basic approach and on single agile manufacturing line and lowers production costs.
Candidate Vehicles: • "The consortium should indicate the military and commercial vehicles that would benefit from the technology...[and in which they can be demonstrated]."	Commercial Vehicles to be built: • 2.48m wheel base, four passenger compact car (EV4) suitable for export markets and which is an important precursor to the production of domestic civilian and military vehicles. • 1.65m wheel base very compact basic electric vehicle (BEV) for export markets which is an important precursor to the production of base vehicles, station cars and other small domestic civilian and military vehicles.
Advances in Technology or Process: • "Technology breakthroughs are sought in any areas that would significantly advance the viability of military and commercial EVs and HEVs." • "...technology that has the potential to be clearly superior in terms of performance and cost to that which can be procured without development."	See Table #5 for details of technological innovations
Pervasive Impact: • "Each project must have competent leadership with pertinent technical, management and marketing backgrounds." • "...must have a [detailed] Business plan...[with] justification for a real-world military and commercial performance need." • "...must summarize the development approach, production methods and estimated production cost of the item."	Competent Leadership: • Amerigon is staffed by managers with a proven track record of commercializing high-volume automotive products. Detailed Business Plan and Customers: • The aluminum running chassis is appropriate for several vehicle profiles. Included in the appendix of the original ARC-4C proposal is a business plan for one of these profiles which illustrates Amerigon's detailed planning for commercialization -- a basic electric vehicle where complex components are manufactured in the U.S. and exported as knock-down kits to Asia for final assembly. Development approach and estimated production cost • The Basic EV has estimated cost of approximately \$4,500 per vehicle (see business plan).
Dual Use • "ARPA's priority is on technology development or demonstrations that are of use to the DOD that can also be used in commercial applications."	Dual-use or shared benefits: • Space frame is suitable for manufacture on single agile assembly line thereby reducing costs and providing for cost competitive production even at relatively low volumes. • Market potential of commercial vehicles can provide base volume to lower costs of frame and components for military use.

B. RELEVANCE OF PROPOSED TECHNOLOGY DEVELOPMENT

Technical Challenges

In order to create a successful Running Chassis technology, several challenges must be met. First, the basic principal must be proven to be feasible. Phase 1 of the Running Chassis Program met this challenge by demonstrating the feasibility of using extruded aluminum and adhesive bonds to fabricate a working prototype chassis. In that phase, an entire vehicle was constructed from aluminum extrusions. It was demonstrated that adhesive bonding of those extrusions could allow great flexibility in the design of multiple vehicles that share a common platform.

The next challenge that must be met involves further developing the basic prototype design into a vehicle that meets desired performance characteristics. Tasks 1,2, and 3 of this proposal address these challenges by developing improved components and refining the design of the frame for low-cost initial fabrication.

The next challenge after that involves developing low cost methods for producing body panels and interiors and for attaching these to space frames in an agile manufacturing environment. Tasks 4 to 10 of this proposal address these needs. (See Table 3 for specifics of the technical innovations that are required.)

Relevance to Military and Commercial Systems

(See section on Compliance with ARPA Project Selection Methodology, above)

Market for Technology

There are three potential markets for this running chassis technology:

- (1) Export sales of knock-down EV kits for assembly and sale in developing countries
- (2) Niche OEMs and EV converters producing low-volumes of EVs for commercial or military markets
- (3) Established major automotive OEMs commercializing mass-market EVs

A detailed description of how these markets will be accessed is included in section D "Business Plans."

Process for Bringing Product to Market

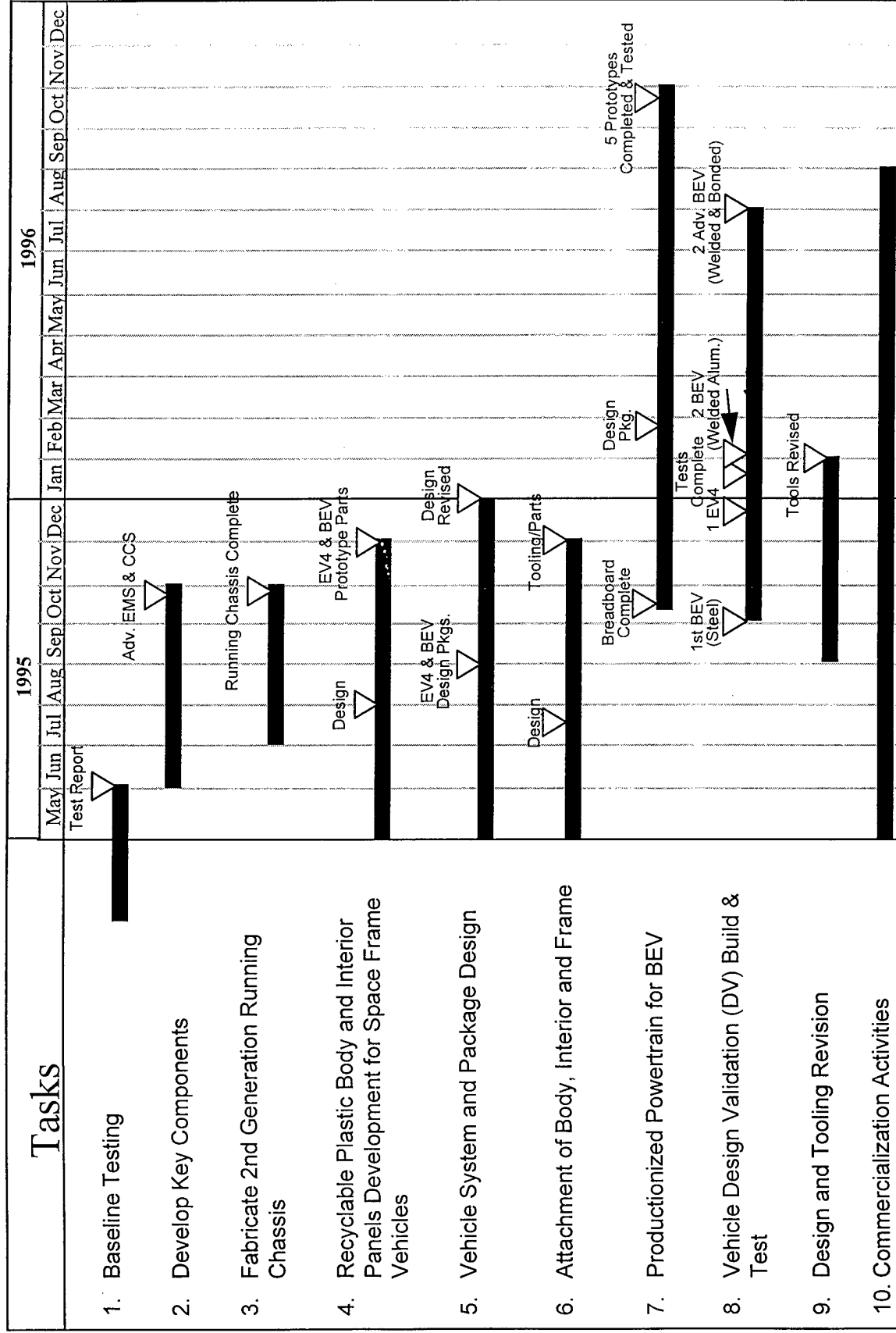
Amerigon has an extensive marketing program in place to present the technology to customers in all three of the target markets. The recent award of \$9 million in commercial contracts for running chassis vehicles evidences this. (See Section D, "Business Plans" for further detail.

C. WORK PLAN

Summary of Tasks, Deliverables and Timetable

A Gantt chart follows with the schedule of activities and deliverables. The breakdown of ARPA contributions and matching funds are shown in Section 3 - "Budget and Payable Milestones."

Running Chassis II Program Timeline



D. BUSINESS PLANTarget Markets

There are three potential markets for this running chassis technology for production of vehicles for either military or commercial use:

(1) Export sales of knock-down EV kits for assembly and sale in developing countries

The running chassis is ideally suited for export as a "knock down kit" to developing countries such as Mexico, China and India that have growing needs for automobiles and policy interests in EVs because of pollution or energy concerns. Knock-down kits are commonly used in the world auto industry where the high value-added components for a vehicle are manufactured in areas with sophisticated manufacturing expertise. The components are then crated and shipped to developing countries where they are assembled into finished vehicles and sold locally. Amerigon is currently under contract to deliver knock-down kits to an Asian customer and is actively discussing plans for delivery of kits to additional customers.

(2) Niche OEMs and EV converters producing low-volumes of EVs for commercial or military markets

Initial discussion have begun with the EV converters in the U.S. about use of the Running Chassis for development of low-volume niche vehicles. Both these companies are pursuing the development of purpose built EVs. However, since initial volumes will be low, the economics of conventional conversion production are not favorable. The running chassis shared platform can address these concerns.

(3) Established major automotive OEMs commercializing mass-market EVs

Active discussions are now underway with several OEM's to undertake production of an electric vehicle based upon the running chassis platform. Amerigon's commercial contract for EVs based on the running chassis support this effort. The advantage to OEMs of this approach is that it can dramatically reduce their costs because of lower tooling needs, and the sharing of all expenses.

The running chassis is ideal for this because:

- The aluminum space frame is easily extruded and formed in the U.S. where this capability is resident because of experience in the aerospace industry.
- EV components (such as motors, controllers, HVAC, wire harnesses, etc.) are all readily manufactured in the U.S.

- Adhesively bonding or welding the aluminum extrusion members is a low-tech, labor intensive process economically suited for developing countries.
- EVs are relatively simple electromechanical devices similar to consumer appliances that are now assembled in many developing countries.

Market Goals

The goal of the running chassis is to have it available for production in early 1996. The dates of earliest availability depend on which of the three target customers is involved, since each has its own requirements for volume and quality. The following table shows target timetables and volumes by customer.

Table 7: Running Chassis Sales: Target Timetables and Volumes by Customer

CUSTOMERS	1995	1996	1997	1998	1999	2000
Major OEMs			10,000	20,000	40,000	80,000
EV Converters		1,000	3,000	6,000	10,000	15,000
Export Knock-Down Kits	100	3,000	8,000	20,000	30,000	40,000

E. RELATED WORK

The partners have directly relevant experience to this project including:

- Successful completion of Phase 1 of the running chassis program that resulted in the development of the first prototype chassis on time and within budget.
- Management and fabrication of CALSTART's Showcase Electric Vehicle demonstrating 20 EV component technologies in an attractively styled vehicle
- Design of a Neighborhood Electric Vehicle for a CALSTART program
- Conversion of several electric vehicles including a Honda Legend for Honda and the University of Hong Kong

Program Management

This program has pulled together a unique team of engineers and designers. The ability to bring together significant experience in all critical areas of EV development and design gives the Running Chassis program a more reliable and more rapid path to develop EVs.

This project will be managed by Amerigon Incorporated, one of the founders of CALSTART. Amerigon's business is the development and manufacture of advanced components and systems for automotive uses, particularly in electric vehicles. Amerigon's managers have extensive experience in producing advanced components for auto manufacturers and have managed the development and production of a "wheels-up" electric vehicle.

The principal management at Amerigon includes Dr. Lon Bell, Dr. Allen Gillespie, and Mr. Robert Diller whose previous company, Technar (now TRW Technar) developed and supplied air bag crash sensors and other advanced components to automakers. Amerigon also manages the Showcase Electric Vehicle program for CALSTART.

The Running Chassis program is managed by Kevin J. Gunning. As manager, Gunning is responsible for orchestrating all of the companies involved in the program to see that each program goal and objective is met according to schedule and within budget. Gunning has extensive experience as Chief Engineer and Manager at TRW Technar where he established and ran a technical office in Japan for working directly with major automotive companies. Mr. Gunning received his B.S. in engineering from the California Institute of Technology and his B.A. in mathematics & physics from Whitman College.

F. FACILITIES AND EQUIPMENT

Amerigon Facilities

Amerigon Incorporated was founded in 1991 and completed its initial public stock offering in June 1993. The company is a high technology firm developing automotive components and systems primarily for use in electric vehicles, low-emission vehicles and other forms of advanced transportation. Many of its technologies also serve the established market for conventional gasoline-powered vehicles.

These products are based on advanced transportation technologies primarily derived from the aerospace and defense industries. Amerigon management personnel have relationships with 19 of the world's major car companies. Amerigon managed the development and construction of the Showcase Electric Vehicle for CALSTART, a complete "wheels-up" electric car featuring advanced technology from California defense and aerospace companies.

Amerigon has over 30,000 square feet of engineering offices and development space. Amerigon has complete design, prototyping and testing equipment and capability. For computer support, Amerigon owns 30 IBM 486 and Pentium microcomputers and 3 UNIX workstations. Application capabilities include four CAD systems for design and FEA, programming in C, FORTRAN and Basic, and full desktop publishing including photo image retouching.

G. PROJECT COST AND COST SHARING

Tasks, key payment milestones and costs associated with those milestones are shown in Table 8: below. All costs are shown in \$1000 increments. Task completion dates are shown by quarter and calendar year.

Table 8: Running Chassis II Program Budget*

ARPA RA-94

Proposed Contract Modification: Final Revision of October 9, 1995

Task	Description	Budget			Milestones & Payment Schedule		
		ARPA	Amerigon Match	Total	Payment Milestone	Payment Amount	Completion and Payment Date
1	Baseline testing of Running Chassis	\$ -	\$ -	\$ -	1.1 Test Report Completed	\$ -	2/1/95
2	Develop Key Components	\$10,000	\$30,000	\$40,000	2.1 Advanced Prototypes Installed in 1st EV4	\$10,000	10/30/95
3	Fabricate 2nd Generation Running Chassis	\$65,000	\$110,000	\$175,000	3.1 Completed Running Chassis	\$65,000	9/30/95
4	Recyclable Plastic Body and Interior Panel Development for space frame vehicles	\$185,000	\$250,000	\$435,000	4.1 Initial Designs Complete	\$155,000	8/1/95
					4.2 EV4 & BEV Prototype Parts Fabricated	\$30,000	11/15/95
5	Vehicle System and Package Design	\$135,000	\$110,000	\$245,000	5.1 EV4 & BEV Design Packages	\$135,000	8/31/95
					5.2 Revised Design packages	\$-----	12/30/95
6	Attachment of Body, Interior and Frame	\$130,000	\$100,000	\$230,000	6.1 Designs Complete	\$45,000	7/15/95
					6.2 Tooling, Parts Fabricated	\$85,000	11/30/95
7	Productionized Power & Control System Production Design	\$50,000	\$20,000	\$70,000	7.1 Breadboard Design Complete	\$10,000	9/15/95
					7.2 Design Package Complete	\$-----	2/28/96
					7.3 5 Parts Fabricated & Tested	\$40,000	10/15/96
8	Vehicle Design Validation (DV) Build and Test	\$115,000	\$40,000	\$155,000	8.1 1st BEV Built (steel frame)	\$75,000	9/30/95
		\$ -		\$ -	8.2 EV4 Built	\$10,000	12/30/95
					8.3 EV4 & BEV Tests Complete	\$10,000	1/15/96
		\$ -		\$ -	8.4 2 Additional BEV Built (welded aluminum)	\$10,000	1/15/96
					8.5 2 Advanced BEV Built (welded and bonded aluminum)	\$10,000	8/15/96
9	Design and Tooling Revision	\$10,000	\$20,000	\$30,000	9.0 EV4 & BEV Tools Revised	\$10,000	1/30/96
10	Commercialization Activities	\$ -	\$40,000	\$40,000	10 N/A (Ongoing Activity)	\$ -	10/15/96
	Total	\$700,000	\$720,000	\$1,420,000		\$700,000	

*These figures are preliminary and subject to minor modifications based upon further refinements of cost estimates. Match dollars may switch between categories substantially, with total exceeding ARPA total funding in all events. Amerigon match funds commence from date of authorization for pre-award costs, 11/22/94. Overhead rate on direct labor is 148% and 8% on outside material purchases.



Modification No. 001
of
Participant Agreement between
CALSTART and AMERIGON, INC.

ARPA RA '94 GRANT No. MDA972-95-1-0011

Modification 001 incorporates the changes as summarized per Page 1 of the referenced Proposed Contract Modification attached hereto.

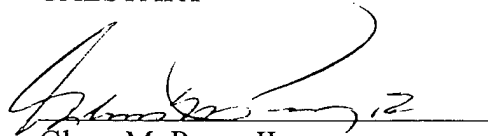
Modification 001 changes the total ARPA Award Amount from \$1M to \$700K

Modification 1 deletes Exhibits A1 and A2 (Budget/Schedule/Milestones) in their entirety and incorporates Exhibit A as shown below.

All other terms and conditions remain in full force and effect.

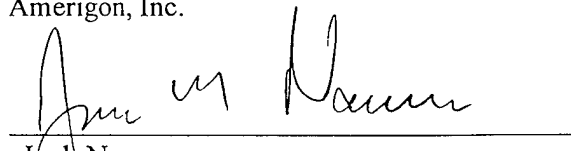
Date	Payable Milestones	ARPA Payment	Match Payment
11/14/95	Initial Payment	\$200,000.00	\$460,000.00
12/31/95	Completion of the following: Breadboard designs of productionized EV drive train; EV running chassis, 1st BEV with steel space frame; and installation of advanced components in 1st EV4.	\$175,000.00	\$200,000.00
03/31/96	Fabricate EV4 and BEV Prototype parts; Fabricate parts for attachment of body, interior, and frame; Revise design package packages for vehicle system and package; Complete build of EV4.	\$125,000.00	
06/30/96	Complete EV4 and BEV tests; Build two additional BEV with welded aluminum chassis; and revise tools for EV4 and BEV.	\$150,000.00	\$20,000.00
09/30/96	Build two advanced BEVs with welded and bonded chassis; Complete design package for productionized power and control systems for BEV; Complete and test five productionized power and control systems for BEV.	\$50,000.00	
12/31/96	Complete Final Report.		\$40,000.00
	Total:	\$700,000.00	\$720,000.00
CALSTART will withhold 10% of each payment until successful completion of the entire project.			
Quarterly reports are required to be submitted with each invoice.			

CALSTART


Glenn M. Perry, II
Chief Operating Officer

Date: 11-16-95

Amerigon, Inc.


Josh Newman
Vice President

Date: 11/20/95



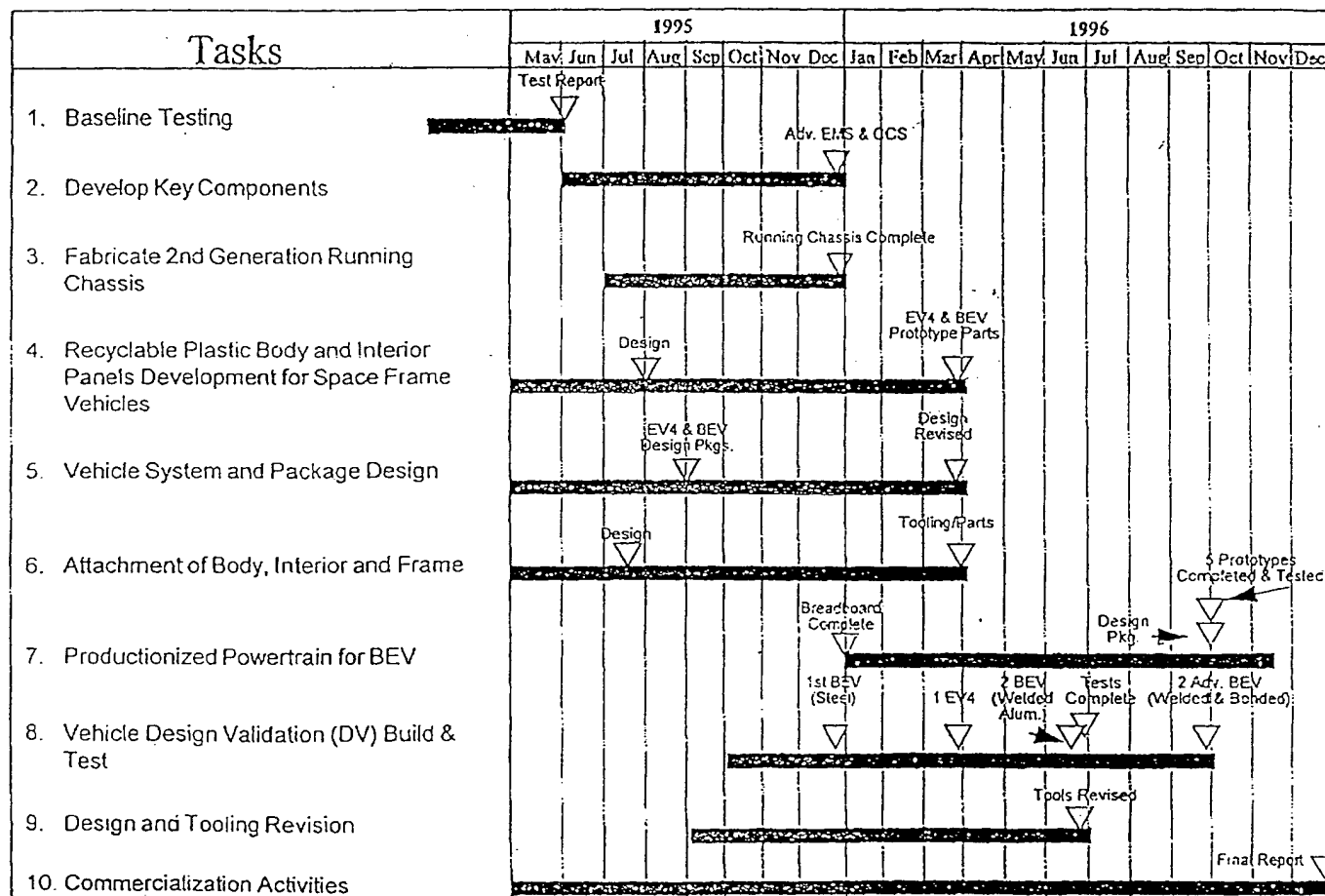


Modification No. 001
of
Participant Agreement between

CALSTART and AMERIGON, INC.

ARPA RA '94 GRANT No. MDA972-95-1-0011

Running Chassis II Program Timeline





Cooperative Agreement MDA972-95-2-0011

Recommended Modifications

September 25, 1996

Exhibit 5



DARPA RA 94-24 Budget and Revisions*
(Cooperative Agreement MDA972-95-2-0011)

Original RA 94-24 Budget		Revised RA 94-24 Budgets	
Original Program	DARPA\$	DARPA \$	Match \$
Optimized 30kW Turbine/Flywheel	600	0	0
Hybrid Electric Vehicle (Rosen Motors)			
Running Chassis Comm. (Amerigon)	500	0	0
Running Chassis Military (Amerigon)	500	0	0
	0	700	700
			Running Chassis II (Amerigon)
Heavy-Duty HE Drive Trains (SBAPCD)	460	350	350
Electric Shuttle Buses (SBAPCD)	100	20	20
			Hybrid Electric Garbage Truck (SBAPCD)
HEV Battery (Bolder Tech.)	550	550	550
			HEV Battery (Bolder Tech.)
Energy Management Controller (Delco Electronics aka Hughes)	175	175	200
			Energy Management Controller (Delco Electronics aka Hughes)
HEV Air Emissions Study (NRDC)	100	100	100
			HEV Air Emissions Study (NRDC)
Data Acquisition System (CALSTART)	150	150	150
Program Management (CALSTART)	369	369	
			Data Acquisition System (CALSTART)
			Program Management (CALSTART)
			Programs Not Listed in Original Proposal
		217	217
		300	300
		90	0
		250	250
			Programmable DC Controller (JPP)
			Catalytic Combuster Dev. & Demo. (Capstone)
			Internet Development and Demo. (CALSTART)
			Distributed Energy Management System (Delco Electronics)
		3271	2837
	3504	3504	Revised Total
Total		233	
Original RA 94-24 Total			
RA 94-24 Budget Less Total			

* Doesn't include NAS Programs (Modification No. 0003) or FY 95 Programs (Modification No. 0004)

9/25/96



**Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
Quarterly Report
July 1 to September 30, 1996**

B-1

Letter from John Boesel to Elaine Ely dated 10/7/96



Via Facsimile and Mail

October 7, 1996

A California Non-Profit

Consortium Developing

Advanced Transportation

Technologies

Board of Directors

Dr. Stephen D. Ban
Gas Research Institute

Dr. Lon E. Bell
Amerigon Incorporated

Mr. Robert H. Bridenbecker
Southern California Edison

Dr. Malcolm R. Currie
Project California

Mr. R. Thomas Decker
Bank of America

Mr. Donald E. Felsing
San Diego Gas & Electric Company

Mr. Michael J. Gage
CALSTART, Inc.

Dr. Richard F. Hartung
Lockheed Martin IMS

Mr. Charles R. Imbrecht
California Energy Commission

Ms. Veronica Kun
Natural Resources Defense Council

Mr. Warren I. Mitchell
Southern California Gas Company

Mr. Michael Peevey
Chairman of the Board

Mr. James Quillin
California Conference of Machinists

Mr. Benjamin M. Rosen
Rosen Motors

Mr. Mitchell S. Rouse
SuperShuttle International, Inc.

Ms. Jan Schori
Santamento Municipal Utility District

Mr. Dennis Tito
City of Los Angeles
Department of Water & Power

Dr. W. Scott Walker
Hughes Electronics

Mr. Richard A. White
San Francisco Bay Area
Rapid Transit District

Ms. Elaine Ely
Contracts Management Office
Defense Advanced Research Projects Agency
3701 N. Fairfax Drive
Arlington, VA 22203-1714

Dear Elaine,

On September 25, 1996 I wrote to you requesting approval of various changes in CALSTART's Cooperative Agreement (MDA 972-95-2-0011) related to electric and hybrid electric vehicle technology. Per our conversation on Friday, I am writing this letter to clarify certain aspects of the September 25, 1996. This letter should be considered as an attachment to the request made in the September 25, 1996 letter.

In the September 25, 1996, I mentioned six projects. I thought it would be helpful to state that of the six projects mentioned, three of them were included in the original RA 94-24 proposal to DARPA. Those three are the Optimized 30kW Turbine and Flywheel Hybrid Electric Vehicle, the Heavy-duty Hybrid Electric Drive Trains and Electric Airport Shuttle buses (actually one project and an add-on), and the Running Chassis for Commercial Uses/Running Chassis for Military Uses (actually one project and an add-on). The other three projects mentioned in the September 25, 1996 letter are closely related but new projects.

In the September 25, 1996 letter, I indicated that the total cost of the Programmable DC Controller project by Jefferson Programmed Power was \$434,000. I want to make it clear that Jefferson Programmed Power intended to pay for \$217,000 and that we were requesting DARPA payment of \$217,000 for that project.

I did not include a proposal for the Internet Site Development and Demonstration. A detailed proposal will be forthcoming. I expect to submit that proposal to you by the end of the month at the latest.





Ms. Elaine Ely
October 7, 1996
Page 2

Lastly, in Exhibit 5, the table titled "DARPA RA 94-24 Budget and revisions", the bottom line in the table indicates that there is approximately \$233,000 in the budget that is presently not allocated to a specific project. Again, a detailed proposal(s) for those funds will be forthcoming in the near future.

I hope this letter answer any questions you or Bob Rosenfeld, the DARPA Program Manager, may have had about my September 25, 1996 letter. If you need additional information, please don't hesitate to call.

Sincerely,

A handwritten signature in cursive script, appearing to read "John Boesel", written in dark ink.

John Boesel
Executive Vice President

cc: Bob Rosenfeld, DARPA



Facsimile Cover Sheet

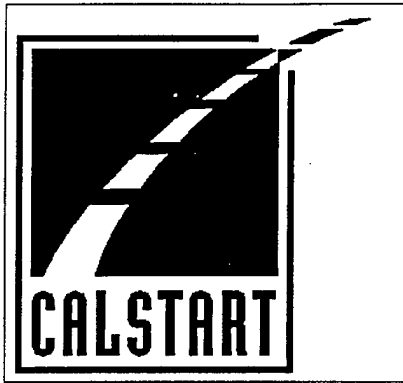
To: Bob Rosenfeld
Company: DARPA
Phone:
Fax: (703) 696-2204

From: John Boesel, Executive Vice President
Company CALSTART
Phone: (510) 864-3005
Fax: (510) 864-3010

Date: 10/7/96 Time: 11:30 a.m.
Pages
including this
cover page: 23

Comments: Attached letter dated October 7, 1996 – providing clarifying information on September 25, 1996 request for approval to statement of work to Cooperative Agreement (MDA 972-95-2-0011).

Hangar 20, Naval Air Station, 1889 First Street, Alameda, CA 94501



Facsimile Cover Sheet

To: Elaine Ely

Company: DARPA Contracts Management Office

Phone:

Fax: (703) 696-2208

From: John Boesel, Executive Vice President

Company CALSTART

Phone: (510) 864-3005

Fax: (510) 864-3010

Date: 10/7/96 Time: 11:30 a.m.

Pages

including this

cover page: 23

Comments: Attached letter dated October 7, 1996 – providing clarifying information on September 25, 1996 request for approval to statement of work to Cooperative Agreement (MDA 972-95-2-0011).

Hangar 20, Naval Air Station, 1889 First Street, Alameda, CA 94501



**Defense Advanced Research Projects Agency
Cooperative Agreement MDA972-95-2-0011
Quarterly Report
July 1 to September 30, 1996**

C-1
Jefferson Programmed Power Final Report

JEFFERSON PROGRAMMED POWER, LLC
M300 D.C. MOTOR SPEED CONTROLLER

Final Report

DARPA RA 94-24
Contract Number 972-95-1-0011

September 20, 1996

Preface to the Final Report

The M300 controller was renamed the Jefferson Clipper to honor the entrepreneurial spirit of the sailors of the clipper ships which brought provisions to the gold miners of 1849 and to recall the historical significance of the other clipper, Pan American's China Clipper which opened the Pacific ocean to commercial air travel.

The creation of the Jefferson Clipper is a milestone in the development of the new generation of electric vehicle controllers not only for its power, versatility and integrated features, but also because the Clipper offers manufacturers a "custom" controller with high-tech programmable features.

We are proud of completing the development on time and on budget. However, the most significant accomplishment is the completion of the project with 20% of the resources a large company would utilize for the development. By contrast, development efforts made by larger corporations generally create new products by selective adaptation of existing technologies. Jefferson Programmed Power started with a clean slate and within 10 months has created the most sophisticated series D.C. motor speed controller in the world.

Jefferson Programmed Power Final Report to DARPA

INTRODUCTION

Our mission in fulfilling the DARPA contract, as we saw it, was to build a product not just to conduct engineering research. Jefferson Programmed Power was successful in that mission by making the Clipper controller, a powerful yet flexible low cost controller for electric vehicles.

The chief challenge in taking up the DARPA contract was to provide a major breakthrough in electric vehicle technology while conducting electronic product development on a modest budget. The labor of talented and committed individuals who donated diverse skills, ranging from management and accounting advice to "C" programming expertise and mechanical design enabled us to supplement paid staff and meet a very rigorous 10- month development commitment for an entirely new electronic product without exceeding the time or the money budgets.

The resultant series D.C. controller is the first in its power range to be based upon a microcontroller. The controller is being vehicle tested and a sales commitment has been received for initial units to be used in a powerful electric sports car.

However as the programmable "brain" of an electric vehicle, the Clipper is equally suitable for specialized military, utility vehicle and fleet uses.

Military vehicle makers and manufacturers of consumer products were formerly faced with the same dilemma when designing an electric vehicle: There was no commercially available low cost motor controller system with regenerative braking, user programmable functions, high-output power, and built-in charger capability. Jefferson Programmed Power built the Clipper to address those needs.

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1. PROJECT GOALS

Our contract with DARPA called for certain goals while creating the Clipper controller:

- A 100KW D.C. motor control section
- Regenerative Braking feature
- Programmable functions
- Battery charger interface and software

Those features which the military would need in a electric vehicle controller also make the controller a unique product for the commercial market. The military vehicle makers and manufacturers of consumer products are both faced with the same dilemma when designing an electric vehicle system: That is, there is no commercially available low cost motor control system with regenerative braking, user programmable functions, high power output and built-in charger capability. Jefferson Programmed Power built the Clipper to address these needs.

2.0 SYSTEM ELEMENTS

The Clipper controller uses a Motorola 32 bit microcontroller with an additional built-in time processing unit (a micro-coded computer within a computer). The computer performs the main function of reading control and signal inputs on input lines then producing output signals to the power transistors which control the torque and speed of the motor(s).

2.1 OEM CUSTOMIZABLE INPUT/OUTPUT CAPABILITIES

The Clipper's computer has 36 digital input/output sense and control lines used for motor control, system status sensing (such as heatsink temperature), and communications. In addition to the dedicated microcontroller input/output lines, the Clipper computer uses the 16-bit data bus to implement an additional 37 input and output lines which can be connected to vehicle electronics. These lines can monitor vehicle conditions and process the information to do such things as cruise control without addition of other components. They can control lamps, read

switches, and monitor safety features. We have created a dedicated 37-pin Amp CPC connector on the back panel, specifically for the OEM's input and output lines.

2.1.1 UNIQUE TORQUE CONTROL IMPLEMENTATION

Virtually all D.C. motor speed controllers for electric cars use voltage mode control to regulate the vehicles' motors. The voltage mode control scheme generally uses the voltage detected at the accelerator pedal's potentiometer to represent a percentage of the battery voltage to be applied to the motor. In other words, if the accelerator is depressed to 25% of its maximum travel, then the voltage across the motor will be 25% of the battery voltage.

There are at least three problems with voltage mode control: The primary problem is the inability of the user to directly control the current applied to the D.C. electric motor when it is stalled or at rest. Even a very small voltage across a stalled D.C. motor can produce a very large torque. This has a tendency to produce jackrabbit starts. While in ideal weather conditions and on highways, the relatively quick start is not a problem, wet or icy conditions could easily produce uncontrollable wheel spin at startup.

A second problem with voltage mode control is the response lag produced when the driver lets up on the throttle and then quickly returns the throttle to its original position. In voltage mode control there is a very perceptible dead-time before the vehicle begins to accelerate again. With some controllers, this lag may be on the order of 3/4 to 1 1/2 seconds before the vehicle resumes the previous speed or begins to accelerate.

The final issue with voltage mode control is inability of the driver to directly control the energy usage of the vehicle. Typically, when the driver depresses the accelerator beyond the 10% point of travel, that will cause the motor to reach the maximum current which the controller will allow for a short period of time. In most vehicle controllers that would be anywhere from 400 amps to 750 amps. This may cause excessive power consumption which is neither desired nor controlled.

The Clipper instead uses torque or current mode control. The accelerator pedal position represents a torque request to the computer. When a driver depresses the pedal to 10% of travel, that action causes precisely 10% of the maximum current to be applied to the motor. Since

current directly translates to motor torque, the driver is not only directly controlling acceleration, but directly controlling energy usage as well. In the situation where the driver releases the pedal, and then quickly returns it the previous position, there is virtually no lag in the response of the controller. The acceleration occurs immediately when the driver needs it.

2.2 EFFICIENCY

We have chosen to use 200 volt MOSFETs for our controller to maximize efficiency. Our controller is a 1.87 milliohm controller which needs no auxiliary cooling, as do most A.C. systems and other high powered D.C. systems. The controller's low resistance translates to a more efficient use of energy by the controller. This mitigates, to a large extent, the greater efficiency of A.C. motors as compared to D.C. motors.

Clipper, 100 Amps of Motor Current					
PWM Duty Factor (Percent of Maximum Vehicle Speed)	20%	40%	60%	80%	100%
MOSFET Conduction Losses	3.75	7.5	11.25	15	18.75
MOSFET and Diode Switching Losses	97.95	97.95	97.95	97.95	97.95
Freewheel Diode Conduction Losses	80	60	40	20	0
Total Power Losses at 100 amps	181.70	165.45	149.20	132.95	116.70
Efficiency (Power at motor/Power delivered)	93.69%	97.13%	98.27%	98.85%	99.19%
IGBT Controller, 100 Amps of Motor Current					
PWM Duty Factor (Percent of Maximum Vehicle Speed)	20%	40%	60%	80%	100%
IGBT Conduction Losses	50	100	150	200	250
MOSFET and Diode Switching Losses	111.94	111.94	111.94	111.94	111.94
Freewheel Diode Conduction Losses	80	60	40	20	0
Total Power Losses at 100 amps	241.94	271.94	301.94	331.94	361.94
Efficiency (Power at motor/Power delivered)	91.60%	95.28%	96.51%	97.12%	97.49%

Clipper, 250 Amps of Motor Current					
PWM Duty Factor (Percent of Maximum Vehicle Speed)	20%	40%	60%	80%	100%
MOSFET Conduction Losses	23.44	46.88	70.31	93.75	117.19
MOSFET and Diode Switching Losses	244.87	244.87	244.87	244.87	244.87
Freewheel Diode Conduction Losses	200	150	100	50	0
Total Power Losses at 250 amps	468.31	441.74	415.18	388.62	362.06
Efficiency (Power at motor/Power delivered)	93.50%	96.93%	98.08%	98.65%	98.99%
IGBT Controller 250 Amps of Motor Current					
PWM Duty Factor (Percent of Maximum Vehicle Speed)	20%	40%	60%	80%	100%
IGBT Conduction Losses	125	250	375	500	625
MOSFET and Diode Switching Losses	279.85	279.85	279.85	279.85	279.85
Freewheel Diode Conduction Losses	200	150	100	50	0
Total Power Losses at 250 amps	604.85	679.85	754.85	829.85	904.85
Efficiency (Power at motor/Power delivered)	91.60%	95.28%	96.51%	97.12%	97.49%
TABLE 1.					
Note: MOSFET data derived from direct measurements and Microsim Spice modeling					
IGBT data used in calculation are from ideal published parameters					

Table 1. MOSFET vs IGBT Efficiency

Unlike most A.C. controllers and other D.C. controllers which use expensive power modules to drive the motors, JPP developed a new power section using discrete components to reduce the cost of assemblies. In doing so we have created a very low impedance circuit which does not produce much switching noise. The reverse recovery voltage spike at the freewheel diode anodes (also at the MOSFET's drains) was measured at less than 18 volts while combined rise and fall times of the voltage waveform was measured at 1 usec. The low noise spike is attributable to very low inductance paths between semiconductors, low resistance paths, and ultra-fast recovery freewheel diodes.

Table 1 compares the Clipper controller's efficiency, which uses MOSFETS, against a comparable controller which uses IGBT transistors. Though the difference in measurable efficiency is only on the order of a few percent, the significant factor to observe is the total power lost in watts. At 250 amps the IGBT controller has to dissipate 904.85 watts at 100

percent duty factor, whereas the Clipper controller only has to get rid of 362 watts of power. This is a manageable amount of heat to conduct from the heat sink to the air and the chassis. But dissipating more than 900 watts becomes a much greater burden upon the system, not only in terms of size and complexity, but also in the cost of the system. The 250 amp figure was chosen as a reasonable power level which would propel a small vehicle at highway speeds.

2.3 INNOVATIONS

Four notable new creations were made for the Clipper controller:

1. User or OEM-programmable control of options and parameters from an IBM PC via an RS232 serial port.
2. An inexpensive proprietary high current sensor
3. An initiation circuit which allows transitioning to regenerative braking at very low speeds--about 10 MPH with the motors and gear ratios used in the test vehicle. This last technology is significant because few D.C. motor speed controllers offer regenerative braking controllers at all. The ones which do have had to limit regenerative braking to lower voltages and lower currents. Vehicle manufacturers which use properly phased motors or motors with interpole windings will find the Clipper controller the most broadly capable regenerative controller available.
4. Battery charger interface to the controller which uses the power components of the motor controller as the power components of a high powered battery charger.

2.3.1 HIGH-CURRENT SENSOR

The high-current sensor was developed prior to the DARPA contract, but its first test during the Clipper development demonstrated its versatility and utility in high powered electric vehicle systems. The Clipper system is designed to work with up to peak 1500 amps of current. In such high current situations requires a current sensor with a margin for current overload. As implemented, the sensor can measure 2500 amps of current with 5 amps of granularity.

The output of the current sensor was scaled to give an output of 1 millivolt per amp of current. On the test bench we tested three of the sensors using an adjustable current generator built by JPP. All three sensor measured currents ranging from 100 amps to 1000 amps with an constant

deviation of 7%. The deviation was analyzed and attributed to small errors in mechanical construction.

The current sensor, when manufactured according to design, is expected to have errors due to construction at less than 2%. The offset errors and slope errors (mVolts/amp) will be corrected in software after a manufacturing calibration procedure.

Because patent application has not yet been made, detailed discussion of its construction cannot be made at this time.

2.3.2 REGENERATIVE BRAKING SYSTEM

The microprocessor circuits and software of the Clipper respond to the state of the system while entering and operating in regenerative braking. The computer is constantly monitoring the current generated from the transformer action of the motor to tightly regulate it the specified level. The proprietary (and likely patentable) circuit, developed in the 3rd quarter of the DARPA contract, allows the Clipper to enter regenerative braking at low motor speeds and currents. This innovation eliminates two major problems with existing circuits. One problem with other manufacturers' controllers is the need for high motor speeds which relies upon the residual magnetism of the field to "tickle" the armature to initiate regenerative braking. This makes for a erratic controller at best.

Secondly, controllers which switch contactors under power risk welding the contacts. Welded contacts pose the potential for un-reliability. In more extreme situations they can creates a hazard. The Clipper controller never switches the contactors while power is flowing through them. This implies that the contacts serve as conductors and are never called upon to make or break hundreds of amps. The Clipper, is therefore more reliable and greatly extends the life of the power contacts.

2.3.3 BATTERY CHARGER INTERFACE

The Clipper is not only as a motor controller, it is also a battery charger. The controller has a dedicated power and signal connector for a battery charger power input on the user connector back panel. The connector is design to interconnect to either on board front-end power conditioner or connected to an external D.C. source. The range of power inputs which the Clipper is designed to accept is from 1500 watts to 6KW.

2.3.3.1 BATTERY CHARGER SOFTWARE TESTING

To support the battery charger software development JPP began the construction of a power supply which would deliver up to 2000 watts of power to the controller. Because of problems with circuit layout problems and noise on the power supply we opted for using battery input to the controller and rectified A.C. as the power sources for the tests instead.

In the first test of the battery charger function, the input power to the controller was fed from a 36 volt battery pack. The voltage was boosted by the controller to 52 volts to charge a separate 48 volt battery pack. The algorithm used in that first test was constant voltage with current limit of 6 amps.

The charger operation was initiated by the detection of the charger input toggle switch. All drive functions were disabled and all contractors were dropped out. The software then calibrated the charger current sensor to accurately determine the zero current setting. After calibration the charger interconnect relay was engaged which connected the 36 volt battery pack to the controller. The power transistors, normally used for motor drive, were then pulse width modulated (PWM) to boost the incoming 36 volts to the 52 volts needed to charge the 48 volt battery pack at the 6 amp rate.

The PWM frequency was tested at selected frequencies from 4KHZ to 90KHZ to determine the useful range of operation. The hardware portion of the circuit dedicated to the charger function worked well at all frequencies. However, in the range above 30 KHZ the switching speeds were not deemed suitable for operation in a full power charger configuration due to the semiconductor inefficiencies and motor inductance in a fully configured system.

The second test used a D.C. source input derived from an isolation transformer connected to the A.C. mains of the building. Connected to the transformer was a Variac which was adjusted to give a 36 volt peak, 120 HZ pulsating D.C. power input. As in the previous test, the current was limited to 6 amps maximum. The charger drew current along the entire period of the sine wave with rather than just at the peaks as do most battery chargers.

2.3.3.2 CONCLUSIONS

The conclusions reached from these initial tests were:

- The additional cost of components internal to the controller to support battery charging up to 6KW is expected to be less than \$28.00 in volumes of 1000 units per year.
- The input power fed to the controller may be from another battery pack or from any commercial A.C.
- The battery charging was performed on the low power tester. The results were sufficiently good enough to warrant continued development. New goals may include up to 10KW of battery charging capability.

2.3.3.3 BENEFITS OF BUILT-IN CHARGER

The benefits of our controller with a built-in battery charger are:

- Lower cost of goods for on-board and external battery charger hardware;
- The major cost items of the charger already exist in the controller; therefore duplication of high priced power components is avoided;
- The power and signal connector on the controller can accept either an on-board battery charger front end or an off-board 6KW input or both inputs;
- Field up-gradable charger parameters mean the charger will not be easily outpaced by subsequent advances in technology;
- The architecture of the charger within the controller is a "boost" topology, which means high voltage battery packs can be supported without hardware changes.

Since the power components in the controller are the heart of the charger and the charger algorithms are resident in the controller's microcomputer, the controller is the charger. By using a stationary 6KVA step-down transformer external to the vehicle (such as in a user's garage) and a few low cost components, the Clipper controller can charge a battery pack from deep discharge to full charge in 3 to 4 hours at an end user cost at about 1/4th the cost of other 6KW charger systems or about \$500.00 in 1000 piece quantity.

2.3.3.4 FUTURE BATTERY CHARGER FEATURES

A future feature of the charger is the proposed storage of battery types, algorithms, and other battery parameters in non-volatile memory. These charging parameters can be modified in the field from our Microsoft Window's user interface. The user will be able to download new algorithms as they become available.

2.3.4 PROGRAMMABLE FEATURES

The programmable features of the Clipper controller constitute an important part of its appeal to OEMs. When a technician on the factory floor connects a personal computer to the external RS232 connectors on the Clipper, the transmit and receive signals are multiplexed to connect to the external computer. When disconnected from the external computer, the signals are multiplexed to the OEM I/O connector so that the controller can exchange data with the dash or other on-board computer.

Some parameters set at the factory will be protected and not alterable by the OEM or the end user. Other parameters may be altered by the OEM and the user, or may be reserved for OEM use only.

The programmable features operate from an IBM PC running Windows software. The user selects a pull-down menu button labeled "PARAMETERS" and a list box give the names of the allowed programmable features. Selecting a parameter and entering a data value causes the new number to be stored in the controller's memory and future operations will use the new value.

Programmable Features	Current	Performance	Diagnostic	Safety Opt.
Main C/L*	X			
C/L Speed 1 Forward	X			
C/L Speed 2 Forward	X			
C/L Reverse*	X			
Plug CL Speed 1*	X			
Plug CL Speed 2	X			
Regen Braking C/L Spd. 1*	X			
Regen Braking C/L Spd. 2	X			
Accelerator Start Disable				X
Brake on disable				X
Heat Sink Overtemperature			X	
Motor Overtemperature			X	
Acceleration Rate 1		X		
Cruise Control Enable		X		
Keypad Entry Enable		X		
Battery Pack Voltage			X	
Door Ajar Alarm Enable				X

Table 2.

Table 2 illustrates some of the implemented and future programmable options.

* These items are presently in the software

2.4 POWER

The Clipper can deliver a peak 150KW of power, but is configurable down to about 50 KW. When operated as a dual motor controller, as is the case with the Zebra car, each motor nominally can operate with 500 amps of current at 144 volts. A single motor drive train would have to use Advanced D.C.'s 9" motor or other high current device.

Higher power is a major feature of the Clipper controller. The following table displays the features of the major commercial controllers which power series D.C. controllers:

Company	Voltage Rating	Maximum Current	Power	Comments
Auburn	144 volts	750 amps	110KW	A, NR, NP, NE, NB
Curtis\PMC (1221-7401)	120 volts	400 amps	50KW	A, NR, NP, NE, NB
Curtis\PMC (1231)	144 volts	500 amps	75KW	A, NR, NP, NE, NB
Dax	144 volts	750 amp	100KW	A, NR, NP, NE, NB
Jefferson Programmed Power	144 volts	1000 amps	150KW	M, RG, PR, EM, BI
Zapi	144 volts	400 amps	60KW	M, RG, LP, NE, NB
Zapi	144 volts	750 amp ??	110 KW	M, NR, LP, NE, NB
Notes: A = analog controller M = Microprocessor control				
NR = no regenerative braking RG = regenerative braking				
NP = non programmable LP = limited programmability PR = programmable controller				
NE = no energy management EM = energy management capability				
NB = no battery charger interface BI = battery charger interface				

Table 3.

2.4.1 OPERATING MODES

The power delivered to the motor is determined by the mode of operation. Implemented modes of the Clipper are:

- Normal drive in forward or reverse
- Plug
- Regenerative braking

2.4.1.1 DRIVE MODE

Direction switch input lines are read by the Clipper computer and direction contactors are energized by the software to cause the vehicle to move in the desired direction. As implemented, the switch input lines are sensed as *Forward1*, *Forward2*, *Reverse*, *Brake1* and *Battery Charger*. Another possible implementation for OEMs could be the sensing of multiplexed switch signal inputs from a pseudo-gear shift lever.

For example, position 1 on the shift lever could actuate switches which are read by the computer and be interpreted as "parking lot" speed settings. The vehicle's acceleration, maximum torque, maximum speed and accelerator pedal sensitivity would then be set to previously programmed values which limit the vehicle's performance for parking lot maneuvering.

In the "optimize" forward shift lever setting, another possible OEM setting, the parameters of the controller could be set to optimize the distance traveled between battery charges. This would be accomplished by limiting the maximum current to the motor, electronically limiting jack rabbit starts and modifying other electronic controls.

2.4.1.2 PLUG MODE

Plug mode operation is the condition that exists when a vehicle is traveling in one direction and the controller is trying to drive it in the opposite direction. This can happen if the reverse switch is depressed while traveling in the forward direction or if a vehicle is rolling backwards down a hill and the requested direction is forward. Plug is a special mode of motor operation which must be sensed quickly because a tremendous torque can develop due to high armature current. Plug mode of operation limits the torque to a pre-programmed setting so that the vehicle will come smoothly to a stop. It is similar to regenerative braking except the energy is dissipated as heat rather than recharging the battery pack. The Clipper's plug braking is an element of the proprietary method of implementing regenerative braking, as called for in the 3rd quarter of the DARPA contract. A patent will be sought for this innovation.

2.4.1.3 REGENERATIVE BRAKING MODE TESTING

The Clipper's regenerative braking system was developed on JPP's low-power tester and then tested on the high-power tester. The regenerative braking software was a 3rd quarter contract deliverable under the contract. The high-power and low-power tests were performed to validate the hardware and regenerative braking software. High-power tests were performed by driving the motor on test stand #1 while test stand #2's motor was being driven by another controller in the opposite direction. The two test stands' output shafts were connected by a flexible coupling. (For further discussion on high-powered the tester, see Section 2.5 below).

Regenerative braking was initiated at relatively low motor speeds, on the order of 850 RPM. This translates to about 10 MPH in the test vehicle. It was observed that when the speed of operation dropped to the point where regenerative braking could no longer deliver battery charging current, the controller transitioned smoothly to plug braking.

Preliminary data from the high powered testing measured battery charging efficiencies of up to 73%. Much of the efficiency of regenerative braking is determined by the characteristics of the motor, gearing, and current limit settings. We expect to see efficiencies of regenerative braking exceeding 80% with other motors and gearing. Our present test motors have a motor constant of .12 ft-lbs per amp which is somewhat low for vehicle motors. Some typical motor constants are .18 to .24 ft-lbs per amp. These higher motor constants not only give greater torque-per-amp but also cause the motors to operate as generators more efficiently.

Our high-powered regenerative braking tests were performed at 12, 24 and 36 volts from our test stand battery pack. We are readying our glider test car to do regenerative braking on a moving vehicle at full voltage and currents to determine the safe levels of operation.

In all modes of operation the controller monitors the heat sink temperature and limits the power to the motor when an over-temperature condition exists.

2.5 HIGH-POWERED TESTER

Though the ultimate goal of any vehicle controller development is to successfully power an electric vehicle, the operation of the controller on stationary high powered test stands yields much more information in the early development stages than can be retrieved from a vehicle in motion.

The high-powered tester was completed in February, 1996, in the second quarter of the development as stipulated in the deliverables of the DARPA contract. JPP built the tester to use pulley belts to drive flywheel weights as an inertia load. The tester permits real currents to be

driven through the controller while the operation is monitored in a controlled environment. When driving the load from a single motor, the tester can effectively operate to about 750 amps of current for a short period of time (about 2 or 3 seconds) with the existing inertia load. To test a dual motor configuration on the high power tester above 500 amps would require the inertia load to be increased to about 1000 lbs. This increased weight would allow 500 to 1000 amp tests to be performed for periods up to about 10 seconds.

Within the next few months, we will be able to dedicate a regenerative braking controller to one test stand (the load) while the unit under test drives the other test stand's motor. The load will provide a braking energy which will be use to recharge the battery pack and will allow testing of controllers at currents in excess of 750 amps for a couple minutes.

Another near-term improvement for the test stand will be to incorporate a regen/brake pedal to apply regenerative braking and hydraulic braking to the flywheel system.



Figure 1. High Powered Tester

3.0 DEVELOPMENT PARTNERING

JPP's concept paper and contract with CALSTART/DARPA stated the desire to include Renaissance Cars, Inc. of Palm Bay Florida, Suntera of Hawaii, and B.A.T. International as both sources of matching funds and in-kind donations and also as partners in evaluating the Clipper controllers. Their contributions were to be the donation of engineering time to evaluate the performance of our controller in their vehicles.

In August 1995, an agreement was worked out with Renaissance Cars' President Larry Henry, under which JPP would use one of their Tropica cars for test and Renaissance would receive a JPP controller for evaluation. Within four months, Renaissance Cars closed its doors. A major portion of JPP's projected matching contributions had been based on Renaissance's anticipated engineering effort.

Suntera of Hawaii is in a similar situation, although the company continues to exist in name. Apparently, Suntera's engineering development and evaluations have been shelved, from the information received.

Though B.A.T. International remains a viable business, the company's anticipated contribution had only a small role in the overall plan to use OEMs as partners. B.A.T. will be sent an beta unit for evaluation, but is not a source of matching funds for the purpose of the DARPA contract.

The shutdown of the two development partners with facilities best suited for low-traffic or off-road testing spurred JPP to develop additional partner relationships. Vehicle testing and engineering evaluation were brought on-site at the Calstart Advanced Transportation Facility. In November and December of 1995, JPP teamed up with the Electric Power Research Institute (EPRI). They loaned JPP the use of two Tropica electric vehicles (acquired by EPRI from Renaissance) as well as fifteen Horizon batteries.

These Tropicas were extremely useful as test vehicles. In order to use them, JPP had to create some specialized tooling to remove the dead battery packs from the cars. At least a week of engineering and fabrication time went into making the tools. This caused a delay in the schedule, which was recovered in subsequent months of the project.

JPP also formed an engineering and business relationship with Zebra Motors, the successor to Renaissance Cars, Inc. Zebra Motors possesses the Renaissance prototypes and intends to manufacture a modified vehicle. Zebra Motors recently placed a verbal order for ten of JPP's Clipper controllers, to be delivered before the end of 1996. The first delivery of prototypes will be on October 22, 1996. Production by Zebra is expected to begin in the second quarter of 1997.

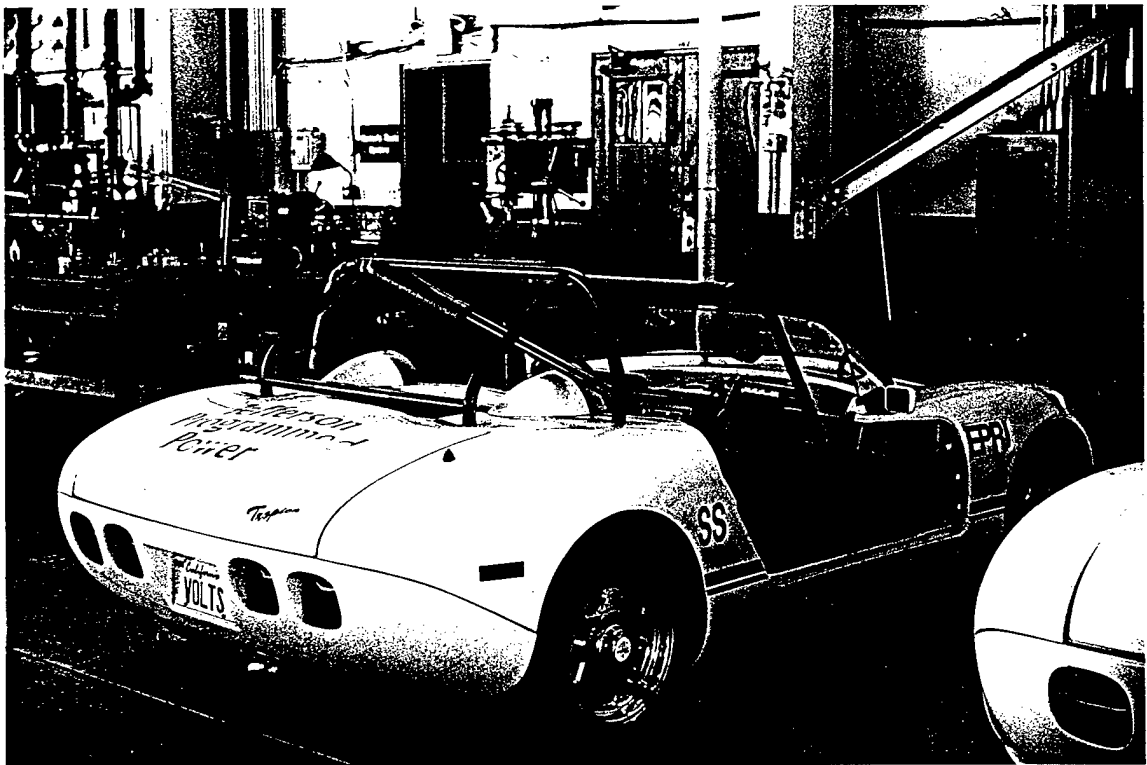


Figure 2. EPRI Test Vehicle #1

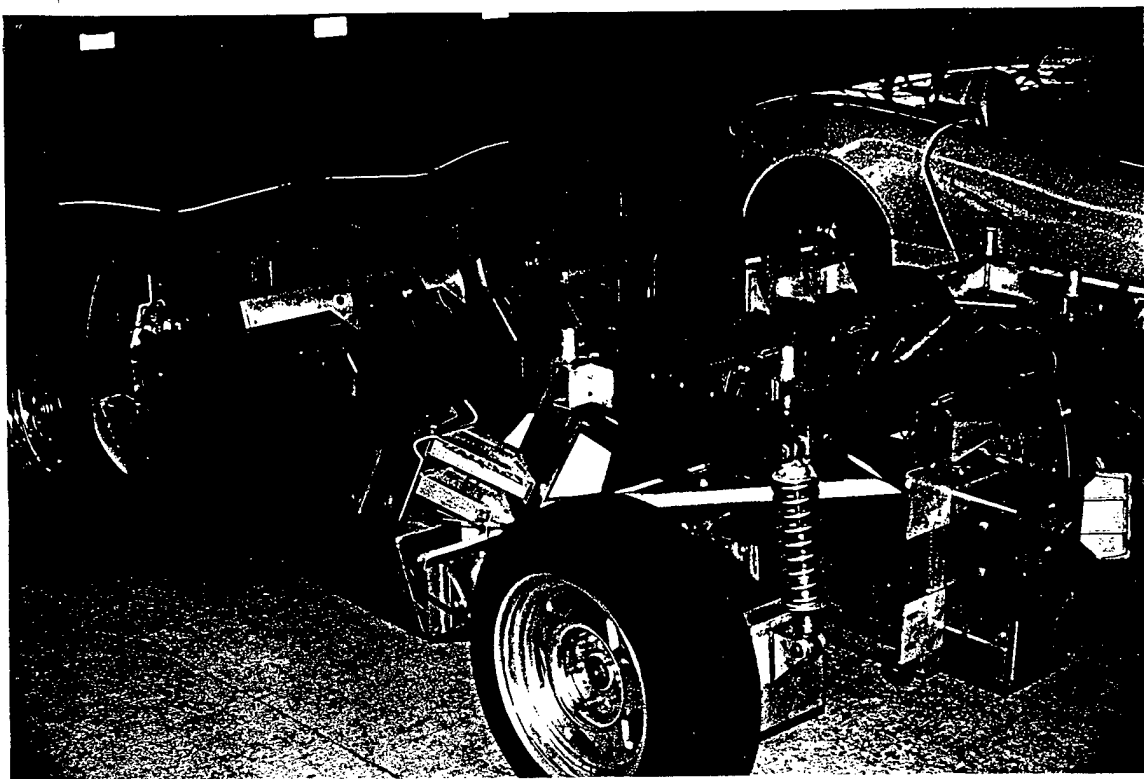


Figure 3. EPRI Glider Test Vehicle

4.0 VEHICLE TESTING

Most development work has to be done on the low-power and high-power testers until the controller's circuits and software have been thoroughly evaluated. The high-power tester allows simulation of actual driving conditions by providing an inertial load. The inertial load is a set of flywheels which are coupled to the motor by pulleys and belts. Motor current, feedback signals, computer interface lines and logic signals can easily be probed during the operation of the high-power tester while conducting significant currents. After the controller has been thoroughly evaluated and all modes of operation have been explored, it can be safely tested on a vehicle under carefully controlled conditions. Considerably more test data can be gathered by having the controller on a static platform, but vehicle testing can provide an environment and conditions that cannot be simulated.

In February of 1996, the first vehicle tests were begun with the glider (the vehicle without body panels) provided by EPRI. Vehicle testing was not scheduled to begin until the 3rd quarter of the development, however JPP engineers wanted to compare the results of static high-powered testing with high current testing on a vehicle. This was an acceleration of the work and the testing was in advance of the requirements under the DARPA contract.

The Clipper controller operated from the glider's 72-volt battery pack and dual motor assembly. The object of the initial vehicle trials was to test the stability of the current control algorithms and sensor feedback under higher sustained current than is possible on the high-power tester. The first vehicle tests demonstrated algorithm stability at 72 volts but less stability at 144 volts. Additional hardware filtering was necessary for the current sensor. The tests revealed the following problem areas:

1. Current sensors were not calibrated-- which produced offset motor current errors. The sensors were tested under high current on a bench-top test fixture to characterize their scaling over the full range of current. An auto-nulling feature was added to the software to auto-calibrate the sensors.
2. At 1000 amps of motor current the conduction paths in the controller developed excessive heat. New bus bars were fabricated to allow maximum current with much less resistance heating
3. The current-regulation algorithm produced a "hunting" behavior which required a change in software. New hardware and software were implemented which allows the current to be more accurately regulated within a small range of values.

In March of 1996, testing of the Clipper in the fully configured test vehicle was begun. The battery pack and mechanical mount was re-designed to accommodate dual 144-volt battery packs. The two packs were installed in parallel and power cabling was upgraded to 3/0 AWG cable. In addition to signal and power cabling changes on the Tropica, mechanical modifications were made to mount the Clipper controller.

In order to install the dual 144-volt battery pack, JPP had to design and build a battery installation tool for the test vehicle. It was constructed using "I" beams with attached rollers. The tool was placed under the test car and raised with a hydraulic jack until the battery pack was lifted a few inches above the battery tray. The battery pack, which weighed about 980 lbs., was

then rolled out of the car on the "T" beam rollers onto an external conveyer tool which extended 10 feet beyond the front of the car.

The initial 144-volt tests had current algorithm stability problems due in large part to defective batteries. The batteries had cracks and voids in their internal bus connections which made some batteries exhibit very high impedance. This analysis was conveyed to JPP by the battery manufacturer about a month after the first tests.

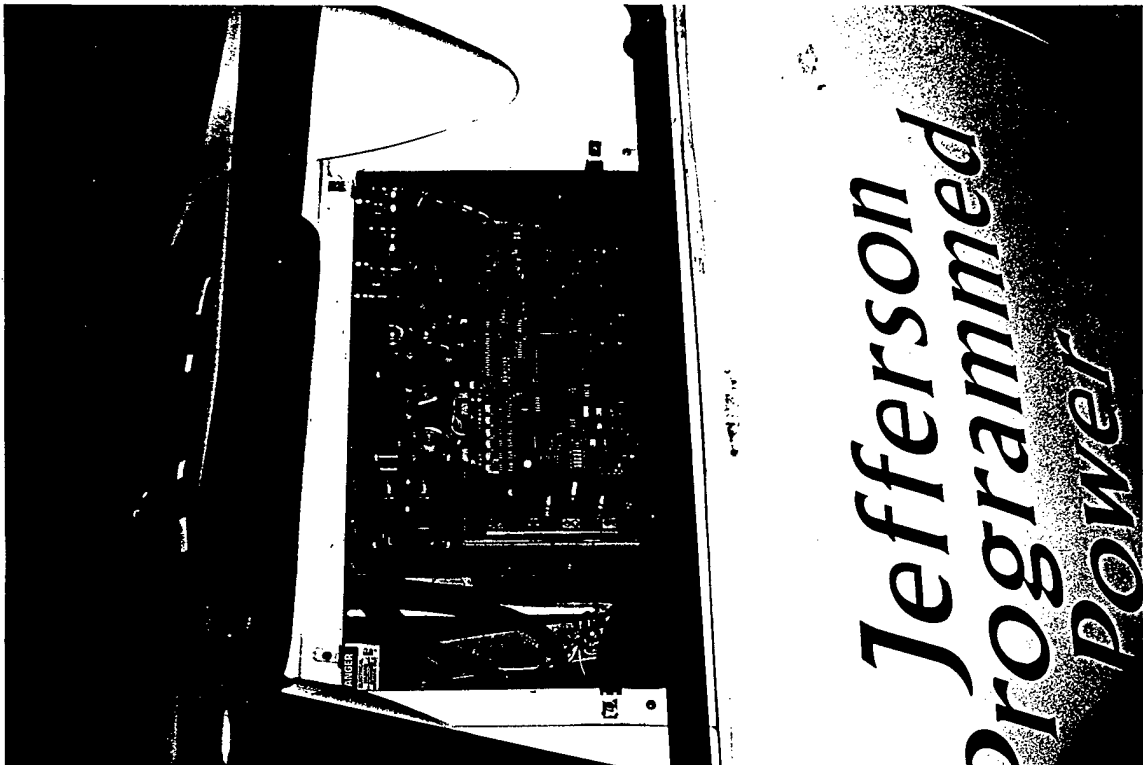


Figure 4. Clipper Installed in EPRI Vehicle #1

After changes in the software to minimize effects due to battery impedance problems, JPP was able to successfully test the 144 volt version of the Clipper controller at high currents on the high-power tester and in the Tropica. Most development work since April of 1996 has concentrated on:

1. Minimizing switching losses by analyzing waveforms on the high-power tester and by evaluating driver circuitry enhancements using Microsim Spice simulations.
2. Heatsink temperature regulation by software control of output power.
3. Minimizing current ripple through algorithm changes.
4. Regenerative braking.
5. Battery charging interface and software.

Development beyond the DARPA contract will include additional vehicle testing to fine tune the regenerative braking mechanism. In the future, the glider will be configured for on-board regenerative braking tests. The emphasis will be on determining the optimum programmable settings for regenerative braking efficiency. Another series of tests will be to determine the brush phasing of the two drive motors, which are turning in opposite directions. The driver-side motor in the glider rotates counter-clockwise when the vehicle is traveling forward while the passenger-side motor is rotating clockwise. The brushes of both motors are neutral-phased, but efficiency of operation may require brush rotation phasing to minimize arcing and power loss at high currents.

5.0 SERIAL COMMUNICATIONS

A multiplexed RS232 communications port on the Clipper controller is configured to connect the transmit and receive lines to the vehicle wiring while normally driving the car. These lines would typically be connected to a master vehicle controller or a dashboard computer.

When an OEM service technician or user connects an IBM PC to the connector on the controller, the RS232 communication lines are switched from the vehicle's computer to the user's computer.

As implemented in the 3rd quarter of the contract, the user interface on the PC is through Microsoft Windows software. JPP software allows the user to select parameters of the controller's operation, such as current limits, from a pull-down menu. The selected parameter's value can be modified by the user, thereby altering the vehicle's performance. When fully implemented and tailored to a specific vehicle, the number of parameters of operation that can be modified may reach the hundreds.

5.1 FUTURE RESEARCH

Future functions that will be supported through the communications interface will include:

- Full screen "dynamometer" with gauges, dials and other indicators displaying real-time data.
- Field diagnostics with user-specified tests.
- The possibility of remote diagnostics through wireless modem communications.
- Battery charger function button which allows selection and alteration of hundreds of detailed features of battery charging algorithms.
- Energy management button for displaying detailed data and analysis regarding recent and historical data on energy management usage and battery performance.

These items are beyond the scope of this contract and additional funding or investment will be needed for implementation.

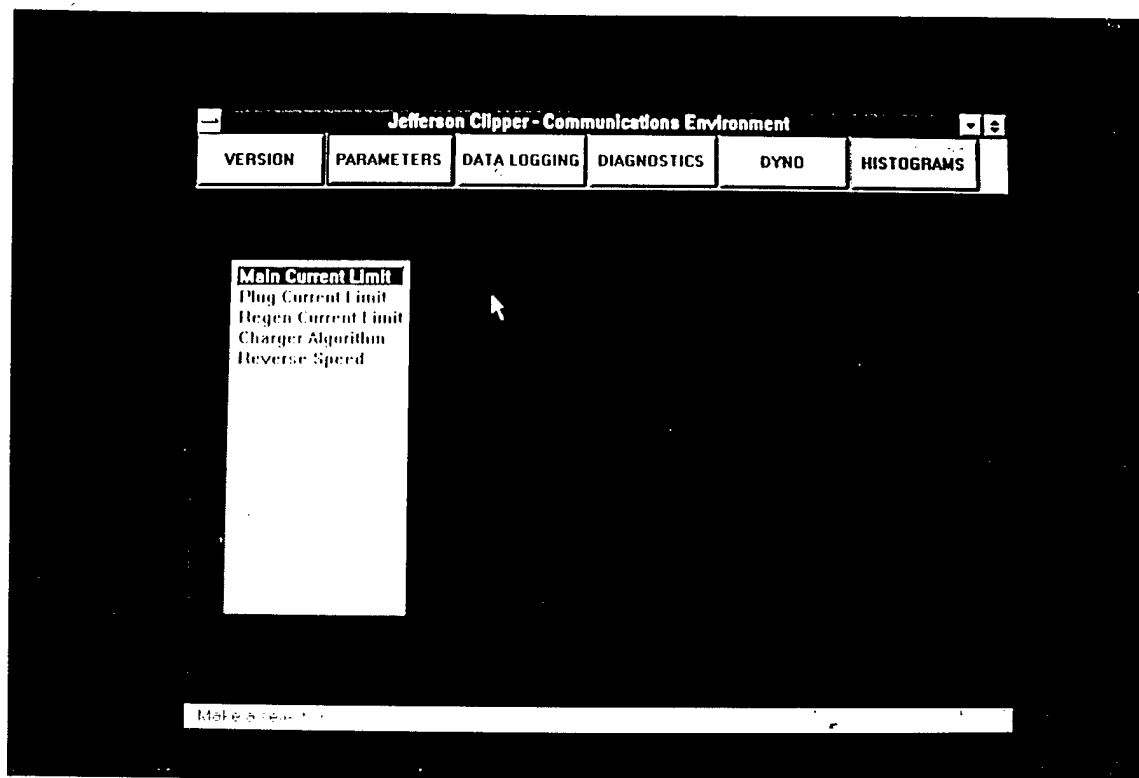


Figure 5. Clipper Windows Interface for User Parameter Programming

6.0 CONTROLLER PRICING

In our initial white paper to DARPA prior to the contract award, we describe 50KW and 100KW controller versions. The 100KW version was to support peak currents of 750 amps at 144 volts. The estimated price of the controller in 10,000-piece quantity would be \$1600.00.

JPP's internal goals were more ambitious than 100KW. We shot for 150KW, or 1000 amps peak current. During the course of development, we found our current conduction paths were initially not up to the challenge. With a couple of extra weeks of work, new bus bars and printed circuit board layouts were created. JPP believes this to be a cost-effective method of achieving our goal. We have given Zebra Motors a preliminary quote of \$1650.00 for 150KW controllers in production quantities. This is a figure which betters our original estimate considerably, since a more powerful controller will be delivered. As designed, the Clipper

controller can address 50KW, 100KW and 150KW applications. This means that a wide range of vehicles can utilize it.

7.0 FURTHER RESEARCH AND DEVELOPMENT

Jefferson Programmed Power is readying its first beta unit for delivery to Zebra Motors for installation into a modified high-performance electric sports car. It will be used as a test vehicle and demonstration car to attract investment money. We will continue to refine the product and ready it for production.

Our other near-term goals which lie beyond the scope of this contract include the following:

- Development of an external stand-alone charger in the 6KW range with target pricing of less than \$500.00
- Development of a motor independent vehicle network controller with integral real-time operating system.
- Adaptation of the Clipper controller for 192 volt operation

SUMMARY

We want to thank DARPA and CALSTART for the opportunity to demonstrate what can be accomplished with very focused research and development from a team of dedicated individuals, operating under a rigorous ten-month development schedule. The resultant controller will facilitate development of the electric vehicle industry by providing a flexible, low-cost option for power control geared to most OEMs' needs.

Appendix A

LIST OF CONTRACT DELIVERABLES

All Contract deliverables were completed by the end of July 1996. Below are the itemize deliverables per the DARPA contract.

FIRST QUARTER DELIVERABLES

HARDWARE

- a. Logic Board Schematic: Logic board schematic completed using Orcad SDT386. **Status: Complete**
- b. Logic Board PC Layout: Logic board printed circuit board designed as a 2 layer 16.2" X 7.65" PCB using Orcad PCB386. **Status: Complete**
- c. Fabricated and Tested Logic Board Tested: 2 logic PCB stuffed with components and one board tested with the low-power tester. **Status: Complete**
- d. Filter Board Schematic **Status: Complete**
- e. Filter Board PCB Layout: Filter board printed circuit board layout, fabrication, and initial component stuffing completed, December 1995, putting us ahead of schedule for the filter PCB. **Status: Complete**

SOFTWARE

- a. Software test routines for RAM, Throttle and Switches: 68332 assembly language test programs written to debug the Logic PCB and lower power tester. **Status: Complete**
- b. Test Software for I/O Functions: Completed basic test software for I/O function validated the integrity of design and PCB layout. **Status: Complete**
- c. A/D Conversion Test Software: Completed A/D test software was used to prove out the designs of the multiplexer, A/D, and input circuitry. **Status: Complete**

TEST

- a. Low Power Tester: The low-power tester allowed simulation of the system. The test now enables us to design and debug software for the test vehicle in parallel with other developments. **Status: Complete**

SECOND QUARTER DELIVERABLES

HARDWARE

a. Second computer logic board completed and tested on both the high-power dyno stand and in a test vehicle. **Status: Complete**

b. Three filter printed circuit cards completed and tested. **Status: Complete**

c. Power board was fabricated and tested. **Status: Complete**

d. Full power testing at 1000 amps performed on the test vehicle. **Status: Complete**

SOFTWARE

a. 'C' language code tested using the low-power test bed. **Status: Complete**

b. 'C' language routines for throttle processing, switch control inputs, plug braking, and rudimentary fault processing implemented. **Status: Complete**

c. Programmable functions demonstrated using the background debug serial communications port of the microcontroller. Programmable functions through RS232 communications port to IBM PC computer complete. **Status: Complete**

d. Two critical programmable functions were demonstrated as programmable: controller current limit and current sensor calibration point. **Status: Complete**

TEST

a. High-power tester assembled, tested and utilized extensively during second quarter of development. **Status: Complete**

b. Current sensor test fixture used to verify calculated values against measured values. **Status: Complete**

c. Both battery packs for the high-power test station assembled, installed and tested. **Status: Complete**

THIRD AND FOURTH QUARTER DELIVERABLES

HARDWARE

- a. Three printed circuit cards (logic, filter and power) of the controller underwent thorough testing. **Status: Complete**

SOFTWARE

- a. Regenerative braking software tested on the low-power and high-power test fixtures. Initial regenerative braking tests indicate a very wide range of operation with good performance. **Status: Complete**
- b. Battery charging software tested on the low-power tester at 300 watts. **Status: Complete**
- c. Microsoft Windows Parameter software interfaces between an IBM PC and the Clipper controller use to alter operating parameters. **Status: Complete**
- d. Fault processing, such as throttle fault detection, RAM check and current limit controls completed, **Status: Complete**

TEST

- a. Clipper controller tested on two different test vehicles. Test conditions of 144 volts and in excess of 1000 amps. **Status: Complete**

MECHANICAL

- a. Mechanical enclosure completed. **Status: Complete**