INTEGRATED TEST VEHICLE PROGRAM PLAN - REVISION C

PHASE II - Deliverable Item 2-7-1
Contract No. EY-76-C-03-1294

Submitted to

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
San Francisco Operations Office
1333 Broadway
Oakland, California 94610

Submitted by

CORPORATE RESEARCH AND DEVELOPMENT
General Electric Company
Schenectady, New York 12301

~~DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED~~

August 26, 1977

GENERAL ELECTRIC

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

The following pages are an exact
representation of what is in the original
document folder.

MASTER

**INTEGRATED TEST VEHICLE
PROGRAM PLAN
REVISION C**

DOE/CS/51294--T5

PHASE II - Deliverable Item 2-7-1

Contract No. EY-76-C-03-1294

Submitted to

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
SAN FRANCISCO OPERATIONS OFFICE
1333 BROADWAY
OAKLAND, CALIFORNIA 94610

DISCLAIMER
This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Submitted by

Corporate Research and Development
General Electric Company
Schenectady, New York 12301

August 26, 1977

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

GENERAL ELECTRIC

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

FOREWORD

C This edition dated August 26, 1977, is Revision C of the Integrated Test Vehicle, Program Plan, Phase II - Deliverable Item 2-7-1. The original edition was issued on May 27, 1977. Corrections were made and issued as Proposed Modifications for Integrated Test Vehicle, Program Plan, dated July 8, 1977. For the purpose of documenting changes, the July 8, 1977, version is called Revision A. The edition dated August 5, 1977, is called Revision B.

C Each paragraph in this edition, Revision C is either unlabeled or marked with an A, B, C, AB, BC, or ABC to indicate technical changes from previous editions. In general, changes in grammar have not been noted. The biographies in Section 2, Management Structure have not been marked for revisions or to note increase in number.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Paragraph revisions on the following pages are indicated in the margins as shown in the key below.

A = A change from the original edition was made in Revision A.
 B = A change from Revision A was made in Revision B.
 C = A change from Revision B was made in Revision C.

AB = Changes from the original were made in Revisions A and B.
 BC = Changes from Revision A were made in Revisions B and C.

ABC = Changes from the original were made in Revisions A, B, and C.

The absence of a letter in the margin indicates that no changes were made from the original edition.

iii	2-10	4-13	4-39	4-69	4-95	6-4
1-1	2-40	4-15	4-40	4-71	4-96	6-10
1-2	2-41	4-16	4-43	4-72	4-97	6-11
1-3	2-42	4-17	4-44	4-75	4-98	
1-4	2-43	4-18	4-47	4-77	4-99	
1-5	2-44	4-21	4-48	4-78	4-100	
1-6	2-45	4-22	4-49	4-79	4-103	
1-7	3-1	4-23	4-51	4-81	4-104	
1-8	3-3	4-24	4-52	4-82	5-1	
1-9	4-1	4-25	4-53	4-83	5-3	
1-10	4-3	4-26	4-55	4-84	5-4	
1-11	4-4	4-27	4-56	4-87	5-5	
2-1	4-5	4-29	4-59	4-88	5-6	
2-4	4-6	4-30	4-60	4-89	5-34	
2-5	4-7	4-31	4-61	4-90	5-35	
2-6	4-10	4-32	4-62	4-91	5-49	
2-7	4-11	4-33	4-67	4-92	6-1	
2-8	4-12	4-34	4-68	4-93	6-2	

Table 1-1
ERDA OBJECTIVES

Parameter	Near-Term ERDA Objectives
Minimum passenger capacity	4 adults
Maximum curb weight, lbs	Open
Minimum urban range (J227D), miles	75
Maximum initial cost, projected, 1975	5000
Minimum life, miles	100,000
Minimum life, years	10
Maximum life-cycle cost, projected in 1975 dollars/mile	0.15
Cost of energy in dollars/kWh	0.05
Maximum electric recharge energy in urban driving, kWh/mile	0.5
Maximum recharge time, hr (115 volts, 30 ampere service)	6
Minimum top passing speed, mph	60
Minimum top cruising speed, mph	55
Minimum accessories	Heater/defroster, on-board charger
Safety features	FMVSS requirements at time of contract
Minimum unserviced park duration, day	7
Maximum years till production ready	5
Maximum critical materials required	Few
Minimum acceleration (0-30 mph), sec	9
Minimum merging time (25-55 mph), sec	18
Sustained speed on 5% one-mile grade, mph	50
Maximum scheduled maintenance, dollars/mile	0.02
Battery type (44 Wh/Kg, 44 W/Kg, ISOA, 1978)	Lead-acid
Minimum ambient temperature range, °F	-20 to +125
Interior noise	Minimum
Turning and braking	No power assist required

C Aerodynamic drag will be maintained at a level which is comparable to the Phase I design -- the goal is a $C_D A$ product ≤ 5.7 square feet.

CHASSIS, SUSPENSION, STEERING AND BRAKES

B The vehicle chassis, suspension and steering will be designed for low weight, good ride and handling qualities, and low rolling drag. Alternate designs will be evaluated for wheel bearings, brake assemblies and lubricants to reduce rolling friction. Low

drag tires will also be investigated and the best tires available will be used. Reductions in tire drag of up to 20% will be a design goal.

B A combined regenerative/hydraulic braking system will be developed which provides safe, easily controlled braking action under all driving conditions. Blending of brake forces will be designed and tested to achieve optimum energy recovery while assuring adequate emergency control. The overall goal is to achieve brake performance and "feel" which is comparable to the best American cars available today.

MECHANICAL DRIVE ASSEMBLY

B Trade-offs between gears and chain drives for coupling of power from the drive motor to the wheels will be examined. Goals for the mechanical drive include low noise, long life and low friction losses. An overall transmission efficiency of 0.98 at normal cruising speeds will be sought.

ELECTRICAL DRIVE SYSTEM

B Improvements in efficiency, performance and production cost will be sought throughout the electrical drive system. Many of these design goals were discussed in the previous paragraphs, and are summarized in Table 1-2.

B A continuing computer analysis will be used to evaluate design trade-offs in the electrical drive system and to optimize the key design parameters of the motor, armature chopper, field chopper, battery charger, and microprocessor.

B The use of a microprocessor to control the electrical drive system offers many potential improvements in performance and efficiency. Because of the flexibility and precision which are inherent in the microprocessor, it will be possible to program the most effective control strategy for each driving mode. The goal to be achieved in this design is to obtain smooth operator control over the entire driving cycle while minimizing energy consumption and preventing serious overloads of the electrical system.

BATTERIES AND BATTERY CHARGER

B Improved lead-acid batteries will be provided for this program by Globe-Union, Incorporated. A design goal has been established to achieve an energy density of 37.5 Wh/kg (17.0 Wh/lb) at the three-hour discharge rate. This represents an improvement of nearly 25% over currently-available (EV-106) vehicle batteries. Goals have also been established for cycle life (500 discharge cycles) and peak power density (220 W/Kg) which are substantially better than existing products.

B To achieve optimum battery performance (hence, vehicle range), the battery charger must be designed to provide a near-optimum

Figure 2-2. Relationship of General Electric Company to ERDA Electric Car Program

EXHIBIT A

B PROCEDURE FOR
PROVIDING TECHNICAL DIRECTION
TO ERDA CONTRACTORS

SCOPE

When technical direction is provided, such direction must be in writing in accordance with the authority that has been delegated and must be within the terms and to the extent contemplated by the contract. While technical direction is issued for the purpose of assuring compliance with the technical requirements and/or specifications of the contract, it must not provide the basis for a contract modification. This function may include:

- Clarifying or more specifically defining, but not changing, the Statement of Work or other technical requirements.
- Recommending or approving approaches to the work to be performed.
- Suggesting alternative methods where the contractor appears to be pursuing an approach that will not fulfill the technical requirements.
- Approving (disapproving) technical work plans, drawings, specifications, test procedures, quality assurance and inspection procedures, reports, analyses, test data, etc.

PROCEDUREInitiating a Technical Direction Memorandum (TDM)

The designated technical manager will prepare a Technical Direction Memorandum (TDM) (Figure A-1) each time he gives technical direction to the contractor involved.

The form will be signed by the originator and distribution made as follows:

- Copy 1 - to the contractor.
- Copy 2 - to the contractor for signed acknowledgement and return to the cognizant technical manager.
- Copy 3 - to be retained by the cognizant technical manager.
- Copy 4 - to Contracting Officer.

Receiving TDM

Upon receipt of his copy of the Technical Direction Memorandum, the contractor will review it to ensure its consistency with

EXHIBIT A

TO (NAME OF CONTRACTOR)		CONTRACT NO.	
(ADDRESS OF CONTRACTOR)		TDM NO.	
THIS TDM IS ISSUED PURSUANT TO THE CONTRACT ARTICLE ENTITLED _____			
PURPOSE ☐ APPROVAL ☐ DISAPPROVAL ☐ CLARIFICATION ☐ RECOMMENDATION			
THE CONTRACTOR IS DIRECTED AS FOLLOWS:			
<p>The directions given herein are within the scope of the above numbered contract and shall not constitute a basis for any change in any of the contract provisions or requirements relating to quantity, quality, fee, fixed price, delivery or performance schedule or any other terms of the contract, nor shall such directions constitute any change in ERDA's obligation to you under any limitation of cost or limitation of funds provision in the contract by your acceptance of this Technical Direction Memorandum. You agree that no claims for change or adjustment in any of the terms or provisions of the above numbered contract will be based upon the directions given herein.</p> <p>If you take exception to anything contained in this memorandum, do not proceed with the directions and notify the JPL technical manager whose signature appears below of such fact as soon as possible, but in any event, no later than three (3) days from the date this memorandum is received.</p>			
SIGNED: _____ Authorized Representative Date		The Contractor accepts this Technical Direction Memorandum without exception. SIGNED: _____ Authorized Representative Date	
_____ Print Name		_____ Print Name	
_____ Title		_____ Title CONTRACTOR	

B Figure A-1. Technical Direction Memorandum Sample Form

EXHIBIT A

the provisions of the contract and with the requirements of this procedure.

B If the memorandum is inconsistent with either the contract or the procedure, the contractor will immediately notify the technical manager and together they will attempt to resolve the issue within the terms of the contract.

Contractor Exceptions to TDM

If the Contractor takes exception to anything contained in the TDM and it cannot be resolved with the technical manager, the technical manager and the cognizant program manager will decide whether to:

- Cancel the TDM; or
- Withdraw the TDM and issue a new one which resolves the exception; or
- Recommend to the Contracting Officer that a unilateral modification or bilateral modification be issued; or
- Take other action as deemed appropriate by ERDA.

Distribution of Executed TDMs

Upon execution by both the JPL technical manager and the contractor representative, copies of the TDM shall be distributed as follows:

- Copy retained by contractor.
- Copy retained by technical manager.
- Copy to ERDA program manager.
- Copy to ERDA contracting officer.
- Copy to JPL Contracts Management Office.

B The General Electric program team shown in Figure 2-3 includes a small nucleus of technical and administrative personnel reporting directly to Mr. Rowland. These people will be employed full time on the ERDA contract and will perform the detailed planning, scheduling, cost control, and technical integration which are necessary to ensure a well-managed program. Other General Electric personnel will be drawn from functional components of the CRD organization to accomplish the design and development of electrical drive systems for the Integrated Test Vehicle. Key members of the design team have been assigned full time to this program. The Drive System Development Project, under the leadership of Dr. J.W.A. Wilson, will draw upon skilled scientists and engineers from the Solid State Power Control Branch and the Power Semiconductor Branch of CRD. Additional design and manufacturing resources will be obtained from several product departments of the General Electric Company. The efforts of these supporting departments will be

The underbody structure will be designed to carry the chassis and bumper impact load.

Lightweight materials for the body structure and the front bumper will be evaluated.

Proven occupant restraint systems will be incorporated into the basic design.

TASK DESCRIPTIONS

Table 4-1 shows the descriptions of the tasks to be performed under Project 3.1.1. Figure 4-3 is a network diagram which depicts the workflow under Project 3.1.1. BC

Table 4-1

PROJECT 3.1.1 - TASK DESCRIPTIONS

Task Number	Title	Task Description
3.1.1.1	Prepare Project Plan	
3.1.1.2	Concept Review Packaging for Mule	Basic vehicle packaging envelope consistent with the marketing and functional aspects will be reviewed using two-dimensional drawings. Battery location and size will actually determine the width of the body. These early concepts will be used to design the mule underbody for seat width, wheel track, front and rear suspension and steering.
3.1.1.3	Body Detail Styling Review and Revision	Determine the revisions necessary from the repackaging study and fabricate a simple seating buck to evaluate seating positions, entrance and egress to both the front and rear seat. The resulting envelope or outline will define the revisions to the outside skin. Adjustments to the skin will require a reevaluation of the aerodynamic drag. This will be accomplished through wind tunnel testing of the revised design. C
3.1.1.4	Modify Phase I Body Drawings for Static Crush Test	Incorporate changes from the repackaging into layout drawing for the full size front end static crush test model.
3.1.1.5	Construct Structural Subsystem - Front and Rear Bumper	Construct a front and rear structural bumper support system from the modified Phase I structural concepts. Attach proposed bumpers, and run preliminary tests for compliance with existing Federal and State regulations, jacking tests, and vehicle towing requirements. Results of test will be incorporated into the final body structural design.

Task Number	Title	Task Description
3.1.1.6	Crashworthiness Prediction (Computer Model)	<p>A computer model of the vehicle will be subjected to impact simulation (both front and rear) and will be utilized to determine the structural requirements of the vehicle.</p> <p>This program has been used in several previous programs and is currently used in the development of the Chrysler Calspan Research Safety Vehicle.</p> <p>Results will be incorporated into the basic vehicle design and subsequently fabricated into the front end static crush test model.</p> <p>Data obtained from the Static Crush Test will be fed back into the computer model for structural modification.</p>
3.1.1.7	Detail Body and Chassis Weight Analysis and Monitor Vehicle Performance	<p>As the detail body and chassis components are designed and modified throughout the program, weights of components will be calculated and monitored to obtain the weight reduction objectives. Since the Basic L-Body is already a light subcompact - light weight material alloys will have to be used to reduce overall vehicle weight. B</p>
3.1.1.8	Body Detail Vehicle Design	<p>Layouts of all body structure and skin panels will incorporate all of the input from the computer analysis, bumper, and static crush tests and the body revisions required due to packaging. Drawings and layouts will be completed to fabricate detail parts. B</p>
3.1.1.9	Data Submittal of MINIBASH Printout	<p>Analytical results obtained from the MINIBASH computer model reflecting test inputs from the Static Crush Test will be submitted to ERDA/JPL. C</p>
3.1.1.10	Prepare Final Task Report	<p>A final report covering the Body Structure design efforts will be written.</p>

PROJECT 3.1.4 - VEHICLE FABRICATION AND ASSEMBLY

OBJECTIVE

Completed design feasibility layouts of the body and chassis and their components will allow the fabrication of components and the assembly of two complete vehicles and one non-drivable vehicle by experienced personnel in a prototype shop. The non-drivable vehicle will be utilized for the 30-mph barrier test as described in WBS Element 4.3. C

TECHNICAL DISCUSSION

Test and development requirements of the completed car and components dictate strict adherence to the material, dimensional, and structural specifications called out on the drawings while timing and economic considerations require processes other than those used in volume production.

The processes used in tooling, fabrication and assembly of these components in quantities from 2 to 100 have been developed to a large degree to meet these unique requirements of the automotive industry.

SCOPE OF WORK

Detail drawings and layouts will be used to fabricate detail parts and components, and subsequently assemble these components into a fully completed vehicle.

TASK DESCRIPTIONS

Table 4-4 shows the descriptions of the tasks to be performed under Project 3.1.4. Figure 4-6 is a network diagram which depicts the workflow under Project 3.1.4. B

Table 4-4

PROJECT 3.1.4-TASK DESCRIPTIONS

Task Number	Title	Task Description
3.1.4.1	Prepare Project Plan	
3.1.4.2	Build and Assemble Two Complete Vehicles and One Nonfunctioning (Barrier Test) Vehicle	<p>Steps involved in building the subject vehicles are identified as follows:</p> <ul style="list-style-type: none"> • Construct wood forms and patterns to fabricate Kirksite dies when required. • Fabricate parts. • Construct assembly fixtures as required to assemble body. • Paint and trim the body. • Fabricate and/or buy chassis components. • Assemble chassis components to the body. • Install instrument panel and wiring. • Install motor and batteries.
3.1.4.3	Prepare Final Task Report	A report covering vehicle fabrication and assembly will be written.

Figure 4-6. Project 3.1.4 Workflow Diagram

Figure 4-15. Project 3.2.9 Workflow Diagram

Figure 4-16. WBS Element 3.3 Workflow Diagram

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

4-80

WBS ELEMENT 4.0 - TEST AND EVALUATION

WBS ELEMENT 4.1 - TEST PLANNING AND INTEGRATION

OBJECTIVES

B The testing and evaluation activity will allow determination of how well vehicle performance adheres to ERDA objectives. This activity will assist continuing optimization versus trade-offs and serve as a design tool at all system levels.

AB The objective of the test planning and integration activity is to provide the overall planning coordination and control required in a comprehensive testing program for the integrated test vehicle, its subsystems and lower component developments. The plans generated will provide the approval interface with ERDA's technical contract manager, JPL.

TECHNICAL BACKGROUND

B In general, tests at lower levels in the system are needed to verify calculations and predictions as well as to set limits. This allows gathering of data which leads to the characterization of components and subsystems. In turn, this leads to making trade-offs and establishing interface specifications between different parts of the system. This trade-off information can be used to allow readjustment to more realistic specifications. Ultimately, the tests will serve to evaluate the final integrated test vehicle before delivery to ERDA. Testing and evaluation must be done on a continuing basis with appropriate changes and redirection, as determined by engineering and in turn, approved by ERDA.

SCOPE OF WORK

B Test plans, test procedures, and special instrumentation requirements will be established to describe test setups, special instruments, component and subsystem tests, electric power system and vehicle checkout tests, and vehicle evaluation tests. Written test plans and test procedures will be prepared and submitted to ERDA/JPL for approval. Testing will be monitored, questionable performance referred to Lead System Engineer (LSE) for resolution, and test plans and procedures updated, as required and as directed by the Lead Systems Engineer (LSE). The LSE's duties will also require that critical test requirements be specified for each subsystem and for integrated vehicle tests. A checklist or matrix will be established to ensure that each critical design requirement is verified by tests or analysis.)

In addition to monitoring test activities at the device, component and subsystem levels, the LSE's main activities will be aimed towards planning and integrating WBS Elements 4.2, 4.3, 4.4 and 4.6:

- WBS Element 4.2 - Special Test Equipment
- ABC ● WBS Element 4.3 - Sled, Static Crush and 30-mph Barrier Tests
- WBS Element 4.4 - Electrical Drive System Tests
- WBS Element 4.6 - Integrated Vehicle Tests

PROJECT DESCRIPTION

Table 4-15 shows the descriptions of the projects to be performed under WBS Element 4.1.

Table 4-15

WBS ELEMENT 4.1 - PROJECT DESCRIPTIONS

Project Number	Title	Project Description
4.1.1	Prepare Overall Test Plan and Review	The program office will prepare an overall test plan for review with ERDA/JPL, which shows the flow of tests from subsystem level through integrated vehicle tests.
4.1.2	Prepare Detailed Vehicular Test Plans and Procedures	Detailed Test Plans will be prepared for vehicle checkout and vehicle tests including in-vehicle subsystem evaluations.
4.1.3	Coordinate Detailed Component and Subsystem Test Plans and Procedures	Test requirements will be identified and placed on component and subsystem vendors (other General Electric components and subcontractors). Detailed test planning by these vendors will be coordinated.
4.1.4	Coordinate Special Test Equipment and Facility Requirements	Requirements for special test equipment and test facilities will be identified and coordinated. Resources will be coordinated and made available as scheduled.
4.1.5	Review and Coordinate Individual Test Plans and Reports	Each individual test plan for components and subsystems will be reviewed and modified with the vendors as required and approved by the Lead System Engineer to insure compatibility with the comprehensive test plans. Each individual test report will be reviewed and results supplied to the LSE. Plans and reports will be coordinated with ERDA/JPL.
4.1.6	Monitor On-Board Subsystem and Vehicle Tests	All testing of on-board subsystems and all vehicle performance tests will be monitored to insure that all performance requirements will be evaluated. All tests and reports will be reviewed and results furnished to the LSE.

AB WBS ELEMENT 4.3 - SLED, STATIC CRUSH AND 30-MPH BARRIER TESTSOBJECTIVESled Test

A The expertise of the Chrysler Proving Grounds Impact Testing Facilities will be used to expedite the optimization of the underbody structure and chassis structural requirements of this vehicle.

Static Grush Test

AB The objective of the Static Crush Tests will be to obtain body structural element crush characteristics which will be used as input data for MINIBASH, a high speed barrier impact computer simulation program.

30-MPH Barrier Test

A The complete body and chassis structure must provide compliance with current applicable industry developed and federally mandated standards.

TECHNICAL DISCUSSIONSled Test

AB The underbody and supporting structure will be evaluated early in the design program by modifying current pre-production components to reflect battery retention system and preliminary front impact structure. Modified underbodies will be evaluated at the Chrysler Chelsea Proving Grounds test facilities. Modified underbodies will use 18 current production batteries, completely discharged, filled with water and ballasted to final battery mass and loading configuration. Test data obtained will be fed into MINIBASH dynamic impact computer simulation program so as to validate design direction prior to full barrier impact.

The following test and recording equipment will be used:

AB • Instrumentation and carriage camera wiring cables are directed from the control console through large conduit in the floor to panels in the rail foundation where they emerge in covered umbilicals to the carriage.

- Capability of up to eight on-board cameras

- Capability for up to 32 channels of data

AB • A sequencing timer will provide starting and stopping signals to cameras, tape and chart recorders, the carriage photographic lighting system and to the Fire Gas Chamber Valve. The timer will provide 300 such signals in a 30-

second period, any of which may be selected so that the instruments are all operating at speed at the instant the carriage is accelerated.

AB • High speed motion picture cameras - minimum of three

AB • Still cameras

Static Crush Test

AB The Calspan static crusher is a heavy duty sophisticated test device. Three cylindrical actuators, powered by a 3000 psi hydraulic system, are servo-controlled for programmed motion of the loading ram. The motion of the loading ram is controlled by two roller guideways and hydraulic servo valves in conjunction with linear position transducers to maintain a single degree angular alignment. The loading controls can be manually or automatically operated for programmed displacement or force loading rates. Load cells located between the hydraulic cylinders and the ram monitor the load output of each cylinder. The displacement measurement is monitored by a linear position potentiometer at the center of the moving ram.

AB The loading ram can be equipped with a special segmented loading surface with four quadrants individually instrumented to record compression loads. Each quadrant can measure a maximum of 45,000 pounds for a total loading capacity of 180,000 pounds.

AB Provisions have been made to continuously monitor the force-deflection characteristics of the test specimen. The individual load cells, the sum and displacement data can also be recorded on a multi-channel recorder. The unit can selectively indicate any of 16 load components measured by individual load cells, the summation of four load components associated with any of the quadrants, and the grand total of all components. During the conduct of a test, all load and displacement signals are recorded concurrently on FM magnetic tape and on strip chart recorders. Energy plots are available as reproductions of tape data displayed on an X-Y recorder. Supplementary pictures can also be furnished.

AB The derived force-deflection properties of the various vehicle elements are next used as input data along with appropriate weights and dimensions to a relatively simple spring-mass computer model, code named MINIBASH.

30-MPH Barrier Test

ABC A barrier test will be performed at Chrysler's Chelsea Proving Grounds impact facilities to verify compliance with FMVSS-204, 212, and 219, as well as to obtain extensive test data for analysis of vehicle impact performance.

AB The vehicle will be tested at rated gross weight. Eighteen Globe-Union batteries, completely discharged and filled with non-corrosive liquid weight, will be used to simulate active batteries.

Masses to simulate actual power plant and transmission will be substituted if prototype components are not available. Two
 ABC fiftieth percentile male dummies will be seated in front seats, restrained with unibelts, and instrumented. Target trap speed is 30.0 mph.

The covered barrier is a facility to create vehicle-to-barrier impacts, vehicle-to-vehicle crashes, and vehicle rollover tests. The building is 100 feet wide by 150 feet long. It houses a 265-ton barrier, a winch with 5000-pound force to, AB propel the test vehicle, two photographic pits, a photographic catwalk 37 1/2 feet high, and a lighting system that consumes 1,300,000 watts to produce 20,000 foot-candles of illumination. The approach runway is 100 feet long.

The following test and recording equipment will be used:

- AB • Photographic reference tubes - These are fixed, accurately marked measuring devices used to indicate distance from the barrier surface. These tubes are mounted on the road surface perpendicular to the barrier face and straddle the test vehicle. The mountings are designed to permit removal and reinstallation of the tubes without changing the position in space of the markings relative to the barrier face.
- AB • Photoelectric trap timer - This device, with its known distance between sensing elements, provides a means for measuring vehicle speed. The timer is located to measure test vehicle velocity within 10 feet of the barrier.
- AB • Barrier force measurement system - Consists of five force plates, each capable of force measurements to 300,000 pounds, mounted to the steel barrier face. These force plates are covered with 3/4-inch plywood.
- AB • Impact timing marker switch - This is a contact switch mounted on the face of the barrier at the first point of contact with the test vehicle. Closing this switch energizes an electrical circuit containing a lamp or neon tube in each high speed camera; the resultant light produces a streak along one edge of the film. The beginning of the streak on the film identifies the moment of barrier impact.
- AB • A pulse generator with a 1000-Hertz serial output and B.C.D. (Binary Code - Digital) timing system - This equipment marks the film for timing identification. This permits correlation of film data with different cameras or with electronic data and establishes an accurate time reference for film and/or electronic data analysis.
- ABC • High speed motion picture cameras (14 cameras will be used to provide total coverage of the vehicle from front, top, bottom, and side views as well as steering column and dummy kinematics).

- ABC • Still cameras (stop action sequence)
- ABC • Mobile instrumentation van (providing 69 channels of data recording capability) consisting of 5 barrier data channels, 32 body and underbody structure channels, and 32 channels for redundant transmission and recording of 16 dummy and seat belt channels

SCOPE OF WORK

Sled Test

- The scope of the sled test will include construction of two front end and body platform structures. These structures will be sent to the Chrysler Proving Grounds for testing and analysis of test results.
- A

Static Crush Test

- One full size model of the front end body structure will be built and sent to Calspan for testing and analysis of results.
- A The rear end structure design and packaging will not be completed in time for this test.

30-MPH Barrier Test

- The scope of the 30-mph barrier test will include the use of existing tooling from the first two cars to fabricate necessary details and components. These components will be assembled to make a third vehicle.
- A

TASK DESCRIPTIONS

- B Table 4-17 shows the description of the projects to be performed under WBS Element 4.3. Figure 4-18 is a network diagram which depicts the workflow under WBS Element 4.3.

Table 4-17

WBS ELEMENT 4.3 - PROJECT DESCRIPTIONS

Project Number	Title	Project Description
4.3.1	Prepare Project Plan	
<u>STATIC CRUSH TEST</u>		
4.3.2	Fabricate Full Size Model	After the review of the Phase I design and all modification requirements are known, drawings will be completed and parts fabricated to build a full size structural crush model.
4.3.3	Test Full Size Model (Calspan)	Full size crush model will be forwarded to Calspan for test and analysis results.
4.3.4	Prepare Report	A report covering static crush tests will be written.
<u>SLED TEST</u>		
4.3.5	Prepare Project Plan	
4.3.6	Fabricate Full Size Test Model	Modify L-Body sedan chassis and underbody platform to reflect modifications required to simulate batteries and other components to simulate weight distribution. A
4.3.7	Test Full Size Underbody Model	Full size dynamic impact model will be forwarded to Chrysler Proving Grounds for testing and analysis of results. A
4.3.8	Fabricate Second Full Size Underbody Model	After review of the first full size test model results all necessary modifications will be incorporated and vehicle will be forwarded to Chrysler Proving Grounds for testing and analysis of results. A
4.3.9	Prepare Report	A report covering dynamic impact test results and design recommendations will be written. A
<u>30-MPH BARRIER TEST</u>		
4.3.10	Prepare Project Plan	A

Project Number	Title	Project Description	
4.3.11	Receive Nonfunctional Vehicle	<p>Receive nonfunctional vehicle which is built and assembled under Task 3.1.4.2. This vehicle will be supplied less the following items:</p> <ul style="list-style-type: none"> • Side and rear glass • Interior and exterior lighting systems • Interior trim components <p>Deliver non-functional vehicle to Chrysler Proving Grounds for barrier testing.</p>	C A
4.3.12	Subject Vehicle to Barrier Test	<p>The barrier test will be conducted at the Proving Grounds with recording cameras and all the equipment needed to analyze the results, i.e., steering wheel penetration, hood penetration, etc. Films will be part of the final documentation report. It should be noted that this test will occur late in the program, at the time the two other vehicles are completed. Revision of the two remaining completed vehicles will not be made.</p>	AB
4.3.13	Prepare Report	<p>A report covering the barrier test will be written. This report will define what should be revised for any subsequent phases if necessary. Technical data from the barrier test will be fed back into the computer model to obtain quantitative recommendations for any necessary structural modifications.</p>	AB

Figure 4-18. WBS Element 4.3 Workflow Diagram

Figure 5-1. Electric Car Program Schedule

be submitted after contract negotiation. The Plan will show key milestones for each program task and will provide a baseline for monthly reporting of schedule status.

MANAGEMENT CONTROL PROCEDURES

The procedures to be employed by General Electric for planning and controlling this program are based on many years of experience on similar Government contracts. The system described below will afford clear visibility of the program's status to the Program Manager and to ERDA/JPL management at all times.

TASK DESCRIPTION

B The Work Breakdown Structure (WBS) presented in Section 3 identifies tasks to be performed. Each task is described fully in Section 4. These task descriptions detail the work to be accomplished. As the program progresses, any change in direction that modifies the work to be done will be documented by changes to the WBS and task descriptions and to the baseline Cost Plan (ERDA Form 533P) and the Milestone Plan (ERDA Form 535).

PROGRAM SCHEDULING

B The program schedule will be expanded after contract negotiations to provide the Milestone Plan for the total design program. Starting dates, critical milestones, and completion dates will be shown for each task. Reporting dates, design reviews, and coordination meetings will also be scheduled as a reminder to the contributing parties. A revised program schedule will be issued whenever the schedule changes or a new task is added. A Monthly Management Report (ERDA Form 536), analyzing schedule status, will be issued as part of the Monthly Progress Report.*

Because the program schedule and task definitions are tied directly to the WBS, each manager can easily ascertain the tasks assigned to him, the dates on which they are to be completed, the amount of money allocated for them, and the interrelationship between his tasks and others.

ALLOCATION OF RESOURCES

Each discrete work package defined for this contract will be assigned to a General Electric component or to one of General Electric's subcontractors for implementation. Labor and material dollars will be allocated to each performing organization to cover the work for which it is responsible. The Program Manager will then monitor the performance of each organization by measuring the technical progress on each task against the rate of expenditure of the funds.

*The Monthly Progress Report includes the Monthly Technical Status Report, Monthly Financial Report, and Monthly Management Report.

[illegible]

COST PLAN

PURPOSE

A baseline plan to allocate costs to each reporting category required in the contract/agreement.

INSTRUCTIONS

- Item 1 — Enter the contract/agreement identification as it appears in the official document establishing the contract/agreement.
- Item 2 — Enter the contract/agreement number as it appears in the official establishing document and append latest contract modification number.
- Item 3 — Enter name and address of the contractor, organization, or agency, as it appears in the contract/agreement.*
- Item 4 — Enter the official start date of the original contract/agreement.*
- Item 5 — Enter the official completion date as of the latest official modification to the contract/agreement.*
- Item 6 — Enter the identification numbers relating to the contract line items, tasks, products, or work breakdown structure elements reported in Item 7.
- Item 7 — Enter the contractually specified reporting categories. A Detailed Cost Plan will be required that allocates cost to contract line item or work breakdown structure. The Detailed Cost Plan will be used as a baseline for monitoring the technical performance of the contract.
- A Summary Cost Plan is required that summarizes complex contract or projects and provides cost information by ERDA Budget and Reporting number.
- A Cost Plan by Cost Element is required to provide cost information in terms of the categories of resources (direct labor, material, etc.) that are planned to be used for the contract or project.
- Item 8 — Enter cumulative planned costs for all prior fiscal years as of the end of the prior fiscal year for each reporting category in Item 7. This information must be the same as that reported on the Cost Management Report (Item 17d) at the end of the preceding fiscal year.
- Item 9 — Enter cumulative actual costs for all prior fiscal years as of the end of the prior fiscal year for each reporting category in Item 7. This information must be the same as that reported on the Cost Management Report (Item 17c) at the end of the preceding fiscal year.

- Item 10 — In the blocks heading each column, identify the reporting periods (months, quarters, etc.) specified in the contract. If months, enter in the extreme left block the first letter of the month for the first contract month with successive months of the current fiscal year as required. If reporting periods are quarters, use 1st, 2nd, etc., enter planned costs by month and total to the right of each reporting category listed in Item 7.
- Item 11 — a through e — Enter fiscal year (e.g., 78, 79, etc.) for each future fiscal year of the contract. Enter planned costs by future fiscal years for each reporting category listed in Item 7.
- Item 12 — For each reporting category listed in Item 7, enter planned costs for fiscal years remaining to complete the program and not included in Items 8, 9, 10, or 11.
- Item 13 — Enter the total planned contract costs for each reporting category listed in Item 7 (sum of Items 9, 10, 11, 12).
- Item 14 — Enter the total costs for each column in Items 8, 9, 10, 11, 12, and 13. Enter only on the final page of a multi-page Cost Plan.
- Item 15 — Enter explanatory notes and comments. If more space is required, attach additional sheets and so indicate in this block.
- Item 16 — Enter the unit of measure for dollar amounts shown above (e.g., exact, hundreds, thousands, etc.).
- Item 17 — Enter date of plan. (This date is referenced in the Cost Management Report to identify the cost baseline.)
- Item 18 — Signature of responsible contractor project manager and date signed, verifying the reasonableness of the information furnished based on his personal knowledge of the contract.
- Item 19 — Signature of the contractor's financial representative and date signed, verifying the reasonableness of the information furnished. Required only on the Cost Plan by Cost Element.
- Item 20 — Signature of responsible ERDA Government Technical Representative and date signed, verifying the reasonableness of the information provided.

*These items need only be entered on the first page of a multi-page Cost Plan.

DELIVERABLE DOCUMENTATION		2. IDENTIFICATION NO.										
		AGENCY	CONTRACT NO.									
1. TITLE TASK REPORTS		ERDA	EY-76-C-03-1294									
3. DESCRIPTION/OBJECTIVE The Task Reports are formal, structured technical reports, submitted periodically to communicate project results for dissemination to Government agencies, the scientific, technical, and industrial communities, and the public during conduct of and/or at project completion. They will be prepared by individual General Electric components or subcontractors as appropriate. The following reports are due on the dates indicated: <table border="0"> <tr> <td>3.1.1</td> <td>Body Structure</td> <td>10/1/78</td> </tr> <tr> <td>3.1.2</td> <td>Chassis, Steering, Suspension & Brakes</td> <td>9/18/78</td> </tr> <tr> <td>3.1.3</td> <td>Air Handling & Electrical System</td> <td>9/1/78</td> </tr> </table> (continued on following page)		3.1.1	Body Structure	10/1/78	3.1.2	Chassis, Steering, Suspension & Brakes	9/18/78	3.1.3	Air Handling & Electrical System	9/1/78	4. WBS NO. 6.2.2	
		3.1.1	Body Structure	10/1/78								
		3.1.2	Chassis, Steering, Suspension & Brakes	9/18/78								
		3.1.3	Air Handling & Electrical System	9/1/78								
5. DUE DATE As indicated in Box 3												
6. APPLICABLE ERDA FORMS (COPIES ATTACHED) None												
		7. DISTRIBUTION 6 - JPL 5 - ERDA/Wash 3 - ERDA/San 1 - ERDA/LA										
8. CONTENTS Typically these reports will include analysis, development and significant design accomplishments.												

3.. DESCRIPTION/OBJECTIVE (Continued)

3.1.4	Vehicle Fabrication & Assembly	3/1/79
3.2.1	Parameter Optimization	9/30/77
3.2.6	Microprocessor Module	2/1/79
3.2.9	Power Modules & Transistors	11/30/78
3.3	Battery System	3/1/79
4.2	Special Test Equipment	5/31/78
4.3	{ Static Crush & Sled Test	3/15/78
	30 MPH Barrier Test	4/28/79
4.4	Electrical Drive System Tests	4/28/79
4.6	Integrated Vehicle Tests	4/28/79
5.2	Differential Cost Report	2/1/79
5.3	Consumer Acceptance Study	2/1/79

DELIVERABLE DOCUMENTATION		2. IDENTIFICATION NO.	
		AGENCY	CONTRACT NO.
1. TITLE TEST PLANS		ERDA	EY-76-C-03-1294
3. DESCRIPTION/OBJECTIVE Test Plans will be created to provide a roadmap for systematic test and evaluation of the major subsystems. Plans will be prepared by General Electric and its sub-contractors. These plans will be provided for the following WBS items: 3.1 Vehicle Systems 3.2 Electrical Drive System 3.3 Battery System C 4.1 Overall Test Plan 4.3 Sled, Static Crush & 30 MPH Barrier Tests 4.4 Electric Drive System Tests 4.6 Integrated Vehicle Tests		4. WBS NO. 6.2.3	
		5. DUE DATE To be assigned at PRD	
		6. APPLICABLE ERDA FORMS (COPIES ATTACHED) None	
		7. DISTRIBUTION 6 - JPL 5 - ERDA/Wash 3 - ERDA/San 1 - ERDA/LA	
8. CONTENTS Each Test Plan will include (1) Broad requirements/objectives (2) General plan (3) Test procedure (4) Test equipment and facilities (5) Data requirements

PAGE ____ OF ____ PAGES

DELIVERABLE DOCUMENTATION		2. IDENTIFICATION NO.	
		AGENCY	CONTRACT NO.
1. TITLE FINAL REPORT		ERDA	EY-76-C-03-1294
3. DESCRIPTION/OBJECTIVE This report is a comprehensive summary of the work done and results achieved on the Electric Vehicle program, covering General Electric and its subcontractors.		4. WBS NO. 6.2.11	
		5. DUE DATE 5/28/79	
		6. APPLICABLE ERDA FORMS (COPIES ATTACHED) None	
		7. DISTRIBUTION Reproducible + 50 copies (no distribution specified)	
8. CONTENTS This technically oriented report of the investigation will be supported as necessary by tabulations of data, figures, and photographs. It covers the following WBS levels:			
<ul style="list-style-type: none"> 1.0 Program Management 2.0 System Analysis and Design <ul style="list-style-type: none"> 3.1 Vehicle Systems 3.2 Electrical Drive System 3.3 Battery System 4.0 Test and Evaluation 5.0 Manufacturing Study 6.0 Documentation

PAGE _____ OF _____ PAGES

Section 6

TEST PLAN

TEST PROGRAM

The general and specific objectives of the test activities were discussed in Section 4, WBS Element 4.1 - Test Planning and Integration. The major activities and tests to be conducted relate to:

- Special Test Equipment (WBS Element 4.2)
- Sled, Static Crush and 30-MPH Barrier Tests (WBS Element 4.3)
- Electrical Drive Systems Test (WBS Element 4.4)
- Integrated Vehicle Tests (WBS Element 4.6)

The approximate timing of the above activities is shown in the condensed schedule, Figure 6-1. This is the same schedule which appeared in Section 5. Not shown on the condensed schedule are lower level tests which are applied at the component and unit level. These tests are described in Section 4 - Technical Approach, under each of the individual discussions. For instance, transistor tests would appear as a task under Power Modules and Transistors (Project 3.2.9). The general test plan will not go to that level of detail so as to provide the individual projects with a reasonable amount of flexibility. This is because some of the activities on the individual projects will be frequently based on vendor contacts and availability; deliveries cannot be accurately pinpointed because some of these acquisitions may be outside of the project control, such as in the case of the development of a new, advanced transistor.

TEST PARAMETERS AND METHODOLOGY

B Thorough instrumentation will be required to measure performance of the overall vehicle and its various subsystems and units. The intention is to build into the prototype vehicles an assortment of transducers with connections which will be routed to a central plug-in board or connector located in an area that is accessible without vehicle disassembly. This in turn will enable plugging in an instrumentation package such as described in WBS Element 4.2 - Special Test Equipment. During the development of the test plan, the various parameters to be measured will be established in detail. A starter list of some of the main parameters which may be measured are listed below:

- Shaft torque (1)
- Shaft RPM (1)
- Voltage (3)
- Current (3)

Figure 6-1. Electric Car Program Schedule

- Temperature (3)
- Draw-bar load (1)
- Watt-hours or amp-hours (1)
- Efficiency (1)

The method of establishing the various parameters will be based on three bodies of information or three activities. One will be established by using a buildup method. Another will be by using a build-down method and a third contribution will result from integrating and cross-checking various specialists and customer inputs.

For the buildup method, the designer or principal engineer on each project or unit will decide which measurements he would like on his particular unit to understand his internal and interface performance. These various inputs will be compiled and common inputs consolidated.

For the build-down method, the broad vehicle specifications and items such as the SAE J227A cycle will be reviewed with the idea of picking those high ranking parameters required to describe total vehicle performance. This activity will start with the vehicle and build down towards the subsystems.

The above two outputs will then be integrated and cross-checked. Screening will take place and priorities or weighting factors will be established for the various measurements on the basis that all suggested measurements cannot be incorporated. Additional inputs will be applied at this stage. These will include customer inputs, i.e., ERDA reports such as "Test and Evaluation Procedure for Electric and Hybrid Vehicle Systems" as compiled by W.J. Dippold.

TEST FACILITIES AND EQUIPMENT AVAILABLE

In general, the test plan will revolve around test requirements and existing facilities. The test plan will serve to determine facility requirements versus usage and scheduling. A broad list of the facilities contemplated for this program is tabulated below:

- General Electric Company
 - Control Development Laboratory
 - Hybrid Controller
 - Full Scale Drive Testing Facility
 - Electric Vehicle Testing and Maintenance Facility
 - Hybrid Computer Facility
 - Semiconductor Processing Facility
 - Semiconductor Device Packaging Facility
- Chrysler Corporation
 - Chemical and Materials Laboratories
 - Dynamometer Facility
 - Impact Laboratory

- Bumper Test Laboratory
- Road Simulator Laboratory
- Stress Laboratory
- Structural Plastic Model Laboratory
- Mechanical Components Laboratory
- Environmental Test Facilities
- Chrysler Proving Ground

A ● Triad Services, Incorporated

- Engineering Design Facilities

B ● Globe-Union, Incorporated

- Engineering Laboratory
- Pilot Process Plant
- Electrochemical Test Facilities
- Materials Testing Laboratory
- Battery Quality Assurance Laboratory
- Advanced Metrology Equipment
- Central Computer Facility

B In order to conduct the total development and manufacture of an electric vehicle, facilities and equipment will be required in the areas of propulsion equipment, traction battery development, and electric vehicle design and manufacture. The facilities described below are evidence of the investment the consortium companies organized for this proposed program are making for the development of electric vehicles. This proposed program will not require the use of government test facilities.

GENERAL ELECTRIC COMPANY*

Corporate Research and Development, the prime contractor on this proposed program, is a component of the Corporate Executive Staff which, in turn, reports to the Corporate Executive Office of the General Electric Company. Corporate Research and Development comprises a company-wide technical resource whose scope includes all of the scientific and engineering fields of present or potential interest to the General Electric Company. Its activities include: analytical, theoretical, and experimental technical work; review, evaluation, and projection of technical and related business information; and consultation assistance. The responsibilities of Corporate Research and Development extend beyond generating new technology to include providing a technical clearing house function and achieving effective technology transfer to and application by the operating business components of the Company.

The work of Corporate Research and Development ranges from the most basic and fundamental research to feasibility studies, prototype engineering, and the transition stage between development and actual production engineering. This work is carried out in three discipline-oriented sectors: Materials Science and Engineering,

*All of the following was Appendix A of original Program Plan