POLICE PATROL CAR PROGRAM

SUMMARY FINAL REPORT

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Abstract

This document is a summary, concluding the efforts of the Police Patrol Car Program of the National Institute of Law Enforcement and Criminal Justice of the Law Enforcement Assistance Administration. The program was initiated in late 1974 with an objective of incorporating into the police car the expressed requirements of the police community for a number of technical improvements and the evaluation and demonstration of an improved police car to enhance capabilities, utility, safety, economy, and, ultimately, police officer productivity.

A prototype vehicle of compact size was successfully retrofitted incorporating:

- fuel and driver aids - designed to increase economy
- improved brakes, seat and restraint systems - designed to increase safety, and
- microprocessor controlled digital communications, display, and data systems - designed to provide greater responsiveness in the command/control environment.

Twenty additional vehicles were planned for retrofit, test, and evaluation in actual police operations in the cities of New Orleans and Dallas. The program was curtailed in March 1977, prior to initiation of field testing.

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I. PROGRAM SUMMARY

A. Introduction

Effective police communications and mobility are critical factors in any attempt to control crime. Every major crime commission since 1931 that has studied police problems has called for substantial system improvements and modernization. Yet in terms of design, equipment, and operation, police systems are by and large one to two decades behind comparable military and aerospace systems. In addition to an effective communications link, the highly trained police professionals should be provided with the means to get them where they are needed--safely, quickly, and economically. Over the years, the demand for police services has increased dramatically, yet no parallel emphasis in the application of available technology had been made to the patrol function, which is one of the major police operations.

On the basis of perceived requirements the National Institute of Law Enforcement and Criminal Justice under the direction of Gerald Caplan initiated a program in late 1974, managed by The Aerospace Corporation, to apply currently available technology to enhance the capabilities, safety, and productivity of police officers through improvements to the vehicles which are the primary tool of the patrol function.

Program objectives were to increase officer capabilities, safety, and productivity by providing real-time access to information stored in the patrol car or forwarded digitally to the patrol car from headquarters and by improving two-way communication capability to support transactions between the vehicle and its headquarters. Command and control during emergencies and other critical times were to be improved by providing hard-copy printout, access to specialized data sources, on-scene situation monitoring, and rapid access to headquarters or other centralized higher authorities. Officer utilization was also to be improved in normal circumstances through the improved command and control communications capabilities.

Safety was to be increased by improvements to the vehicle braking and warning systems, provision of a "hands-free" voice communication capability, and incorporation of better seats as well as inclusion of other interior design considerations for occupant safety. Economy was to be increased through utilizing such concepts as incorporation of compact-size vehicles, improving the maintainability of the vehicle, and providing driver aids for monitoring vehicle conditions and fuel economy. Human and equipment interfaces were to be improved through optimum location of equipment and displays and inclusion of features to achieve maximum officer comfort and effectiveness over extended patrol periods.

A number of existing technological developments applicable to improving police patrol car systems were incorporated in a prototype vehicle to demonstrate improved systems capabilities, evaluate the operational suitability, and provide early identification and elimination of systems design problems.

Twenty vehicles were to be modified to include improvements selected as most promising and/or cost effective. These modified vehicles were to be utilized for a field test demonstration and evaluation in actual police department operations.

B. Prototype Development

Development of the prototype vehicle systems described was based, inpart, on the planning conference held in January 1975 with the Chiefs of Police Advisory Council (Figure 1-1), LEAA, the National Institute of Law Enforcement and Criminal Justice, and The Aerospace Corporation. The purpose of the conference was to exchange ideas with and solicit comments and guidance from the police community prior to development of the prototype vehicle. As a result of data obtained from this conference plus information gleaned from previous studies, the capabilities selected for the improved police patrol car program emerged.

1. Economy

A compact car, incorporating driver aids to encourage more economical driving habits, vehicle diagnostics (which would provide timely information thereby contributing to better maintenance), and an improved ignition system, provided an estimated fuel consumption of 15 miles per gallon representing approximately a 100-percent increase in economy over current police fleets. With such cars, the extrapolation of expected savings to the total U.S. police car fleet indicated that an annual fuel savings of $250 million were possible. Other postulated savings were a decrease in maintenance and repair cost of $260 per car or $42 million per year and a decrease in vehicle replacement cost of $1550 per car or $82 million per year.

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Chief, Colorado State Patrol

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Sheriff Peter J. Pitchess
Los Angeles County

Col. John R. Plants
Group Manager
Automobile Club of Detroit

Chief Rock Pomerance
City of Miami Beach

Commissioner Philip G. Tannian
City of Detroit

Figure 1-1. Members of the Police Patrol Car Program Police Advisory Council

2. Safety

The second major goal of the program was to enhance vehicle safety and provide a more comfortable environment for the police patrol officer. Key components or systems installed included four-wheel antilock brakes, a wide-angle rearview periscope mirror, a carbon monoxide sensor, a hands-free communication system, and an improved front seat and restraint system.

The four-wheel antilock brakes were intended to enable the car to stop in shorter distances while remaining under full control on wet, snowy, or icy pavements; the 70°-wide unobstructed viewing angle over the car roof enabled the officer to maintain better surveillance to his rear and assisted him in driving more safely when maneuvering in heavy traffic. A carbon monoxide sensor was incorporated to monitor both the instantaneous and cumulative carbon monoxide concentration in the car and to automatically alert the vehicle occupants and the base station dispatcher when levels approached or exceeded the accepted level of safety.

The seating and restraint system improvements provided the driver and the patrol partner with individually adjustable seats that were designed to provide maximum seating comfort over extended time periods. The restraint system was designed to alleviate three major problems--discomfort when worn for extended periods, impediment to rapid egress, and interference with the officer's belt-mounted equipment. The hands-free communication equipment enabled the driver-officer to initiate and maintain communications without removing his hands from the steering wheel. Such operation would be of particular benefit during high-speed or emergency operation.

3. Effectiveness

One of the more important features of the prototype vehicle was the microcomputer-controlled digital communications system that included an onboard data base. This system could increase the officer's productivity in several ways. It provided a fast and secure communications system able to store and retrieve messages and files of important data. After completion of an incident, this system allowed the officer to file the incident report directly from the car to the base station computer without filling out forms. The patrol officer could communicate directly with the base computer for routine information checks (e.g., stolen vehicle data file). With this system, more information checks would be encouraged, and more rapid response would be provided.

Another application was the capability of furnishing routine roll-call information to officers via an onboard digital tape cassette which could be handed to them when they went on duty. The information could be displayed on the patrol car terminal, thus saving at least some of the time now spent in the daily roll-call meetings.

A hand-held digital/audio communications terminal was also incorporated. The patrol officer could carry this device when leaving the patrol car, enabling the maintenance of contact with another officer in the car or with a dispatcher at headquarters.

The incorporation of a microcomputer in the vehicle also made it possible to obtain vehicle diagnostic benefits at a nominal increase in system complexity and cost. This bonus was derived from the excess computational capacity beyond that required for data system control and management.

The vehicle diagnostics were obtained by installing a number of sensors in the vehicle which measured engine temperatures, pressures, fluid levels, vehicle speed, tire pressure, and status information such as doors (open/closed), lights/siren (on/off), etc. This information, after computer processing, could then be used for the following purposes:

- Constantly checking for impending or actual out-of-limit operating conditions and automatically alerting driver and/or dispatcher,
- Permitting driver and/or dispatcher to check vehicle operating status,
- Providing a hard-copy vehicle status printout for maintenance department review and action, and
- Building up a large data base stored in the central computer which would enable complete analyses of fleet operations.

A general increase in productivity would be expected to result by enabling better scheduling of maintenance and reduction of vehicle downtime.

Subsequent to development of a major portion of the prototype vehicle systems, another conference with the Chiefs of Police Advisory Council was held on March 16, 1976. At this time, the prototype vehicle systems were demonstrated, and recommendations and suggestions were solicited from the Advisory Council.

C. Field Test Program

Definition of the systems requirements for the field test program was based on the results obtained from the prototype vehicle development and the results of the March 1976 conference with the Chiefs of Police Advisory Council.

The knowledge and experience derived from the planned field test demonstration and evaluation were to have been widely disseminated throughout the law enforcement community and its industrial suppliers and would, hopefully, result in the commercial availability of improved equipment. This equipment could then be selectively utilized by police agencies according to their specific needs.

D. Vehicle Configuration Improvement Studies

In parallel with the vehicle and data systems improvements, several vehicle configuration improvement design studies were performed. Design studies on compact alternate body configurations were to develop and assess concepts that provided improved human and equipment interfaces, increased interior volume, greater overall utility, and reduced vehicle weight. A study of candidate drive-train systems to provide a dual-mode performance capability was initiated. Economy mode (nonemergency driving) and power mode (emergency response driving) requirements were developed, and candidate systems assessed costs and expected savings in fuel consumption relative to currently used cars. Finally, a study to evaluate vehicle locator systems and the extent of data system design consideration to accommodate candidate vehicle locator systems was conducted.

E. Test Site Selection

At the onset it was stipulated by LEAA that tests would be limited to two cities due to the economics involved (i.e. contract funding). The basic requirements for qualifying municipalities were that the police department:

- Provided a program compatible with patrol car improvements;
- Operated in urban, suburban, and highway environments;
- Used digital communications for command and control; and
- Was experienced and available for participation in experimental projects.

An additional constraint for selection was the compatibility between the development data system and the local command communication system. The considerations for these requirements included:

- Availability and compatibility of radio hardware;
- Federal Communications Commission regional constraints;
- Availability of support for software, interface, and development;
- Dispatch and inquiry operation compatibility;
- Degree of automation and convenience of interface; and
- Support of direct data base inquiry from field units.

Following a thorough analysis of the requirements and capabilities, the cities of New Orleans and Dallas were approved by the Law Enforcement Assistance Administration as sites for the field test program.

F. Program Termination

The Police Patrol Car Improvement Program was initiated in December 1974 and was terminated in March 1977. The principal reasons for the termination were the following:

1. Engineering

   a. Although state-of-the-art equipment had been successfully integrated into the prototype vehicle, considerable additional development would have been required to optimize weight and power, and demonstrate total system viability.

   b. Model year differences between the prototype and test vehicles required additional re-engineering of the state-of-the-art integrated equipment packages. While the 1976 Novas were similar to the 1975 prototype, the necessity of using 1977 vehicles in the field test phase required a complete re-integration and retrofit design effort.

2. Time

   a. The anticipated additional engineering requirements were expected to prolong the retrofit and testing periods by one to two years beyond programmed completion dates.

3. Costs

   a. Engineering modifications and time extensions would increase costs beyond the $2 million already expended.

   b. Bids received from prospective subcontractors far exceeded estimated funding.

   c. Revised cost estimates to complete the program exceeded an additional $2 million.

4. User Demand

   a. Initial support from the police community decreased because of the general scaling down of automobile sizes by the industry, making smaller cars the standard rather than the exception.

b. Indications were that many of the innovations (integrated packages, component scale-down, etc.) were or shortly would be available commercially.

c. Many police departments have planned or implemented integrated digital communications and display patrol car systems.

II. PROTOTYPE DEVELOPMENT

A. System Description

1. Improving economy. The following concepts were identified as having potential for improving the economy of the patrol function.

a. Compact car. Significant savings in fuel cost could be achieved by using a compact car. By using a lower weight vehicle than the standard sedan and by keeping other factors constant (e.g., ratio of engine size to vehicle weight), savings of several miles per gallon could be expected. In addition, compact cars had lower maintenance history cost than standard size cars and the lower new car price and reduced depreciation rate of compact cars would result in significantly lower acquisition and replacement costs.

The basic automobile for the prototype police car was a 1975 Chevrolet-Nova four-door sedan in the police configuration. The Nova police equipment package included a high-capacity cooling system, Chevrolet's 350-cubic-inch displacement V-8 engine with a 4-barrel carburetor, heavy-duty front suspension, oversize brakes, and numerous other features to improve reliability, comfort, safety, and performance. The following is a list of the factory installed equipment options included in the prototype vehicle.

- Special Options (COPO9C1) Police Chassis Equipment Package

  350 CID V-8, 4-barrel engine

  Turbo Hydramatic transmission

  Power steering

  Engine durability features, such as oil cooler and heavy duty bearings

  Special performance suspension including 14 x 7 wheels and special rear spring bushings

Front and rear seats trimmed in heavy duty vinyl

High capacity cooling system with special temperature-controlled fan and clutch

Heavy-duty, 4000-watt battery equivalent to 80 amp hour

Sport steering wheel

- Tires

Firestone Kevlar FR 70-14 (commercially available)

- Regular Production Options

Tinted glass--all windows

Pulse-type windshield wipers

Rear window defogger--forced air

Air conditioning

Day/night inside mirror

Rearview mirror--L. H. remote control

Positraction rear axle

Comfortilt steering wheel

Dual horns

- Special Order Options

Transmission low gear block out

Heavy-duty front floormat

Single key locking--single vehicle

Rearview mirror--R.H.

Cigarette lighter

Power disc/drum brake system including metallic impregnated front lining

80-amp generator (58-amp at idle)

Locking gas cap

Luggage compartment lamp

Special police speedometer, 2-mph increments, certified accuracy

Certain modifications to the basic vehicle were required to accommodate the improved systems which were added to the vehicle. The increased weight required the installation of extra heavy-duty rear springs, and the power requirements necessitated installation of an additional battery and the replacement of the 80-amp police package alternator with a 130-amp alternator.

b. Vehicle diagnostics. A concept called "vehicle diagnostics" offered across-the-board benefits in terms of a more economical, a safer, and a more productive police vehicle. This concept involved continuous monitoring of special sensing devices in the vehicle and relaying of the outputs of these devices to the patrolman or back to the base station. When the sensors detect out-of-tolerance performance, appropriate diagnostics are displayed to alert the patrolman, and a status message is transmitted to the base station. The diagnostic data relating to engine and vehicle performance could be used by the maintenance department to anticipate problems before failures occurred. In this way, a maintenance program could be implemented which would be a middle road between the high-cost approach of scheduled preventive maintenance and the lower-cost, but potentially disastrous, plan of driving the vehicle until it is inoperable. Improved maintenance would also result in a better-tuned engine, with the attendant improvements in fuel economy. From the standpoint of safety, the patrolman would be able to anticipate dangerous conditions, such as low tire pressure, abnormal catalytic converter temperatures, and dangerous carbon monoxide levels in the passenger compartment. Productivity could be improved by scheduling maintenance to require minimum downtime and by utilizing the diagnostics data in an operations analysis of the patrol function. In addition, the diagnostics data could be of great assistance in determining the use of the experimental systems during the field test.

The sensing devices monitored by the vehicle diagnostics system were divided into two types: those which provided direct measurements, or analog outputs, and those which provided yes/no or on/off discrete outputs. The functions associated with each type of sensor are listed below.

Direct Measurement Functions

Battery voltage

Fuel flow

Fuel used

Fuel level

Distance traveled

Vehicle speed

Engine speed

Oil pressure

Oil temperature

Coolant temperature

Transmission oil temperature

Exhaust temperature (inlet and outlet sides of the catalytic converter)

Carbon monoxide concentration

On/Off Discrete Functions

Tire pressure ok/low

Seat belt in use (yes/no)

Coolant level ok/low

Engine on/off

Brake system - Brake pedal depressed (yes/no); Antilock brake system enabled (yes/no); Antilock brake system modulating brakes (yes/no)

Headlights on/off

Siren on/off

Warning lights on/off

Hands-free communications system in use (yes/no)

Driver in/out of seat

Car door open/closed

The direct measurement sensors generally are available as standard automotive components.

c. Driver-aid devices. Direct readout of miles per gallon and manifold pressure served to alert the driver to conditions that produce poor fuel economy and aided the driver in developing and maintaining economical driving habits during nonemergency operations. In addition, data were transmitted to the base station, which permitted continuous monitoring of fuel consumption and compilation of records that could be used to compare various uses of the vehicle as they affect fuel economy.

2. Emergency warning and safety systems

a. Light Bar. Two emergency warning light bar configurations provided independent subsystems so that either configuration could rapidly be installed on the vehicle for comparison. The two light bar configurations, revolving and strobe light configurations, each consisted of signal lights, alley lights, and a spot/flood light. For both the revolving and strobe light configurations, it is possible to evaluate various light color combinations by changing bulbs and/or lenses. The signal lights consisted of a steady-burning, red light facing forward and flashing red and amber lights facing the rear. The spot/flood light had the capability to rotate clockwise and counter-clockwise at varying rates and to move up and down.

Two speakers were mounted on each light bar configuration to provide a siren/public address system. The siren was capable of being operated in the manual and wail-plus-yelp modes. In the manual mode, the siren was actuated by pressing the horn ring. In the wail-plus-yelp mode, pressing the horn ring automatically shifted the wail to yelp for 5 seconds. The siren speakers had the capability of accepting experimental signals that have been developed to maximize sound penetration. The experimental signals were produced from a cassette unit. The system was capable of operating as a public address system with the use of either a microphone or radio system input.

The siren, revolving or strobe lights, the signal lights, the alley lights, and the spot/flood light were operated from a central control panel. This panel had an accessory switch module which controlled six warning light functions by means of rocker switches and included controls for operating the tape input to the siren.

b. Carbon monoxide monitor. A system that monitors both the instantaneous and cumulative level of carbon monoxide in the passenger compartment provided a capability to detect dangerous levels of this poisonous gas and to sound an alarm. The effects on a patrolman of exposure to carbon monoxide gas can range from headaches and impairment of functions to death, depending upon the concentration of the gas and the exposure time.

c. Hands-free voice communications systems. Two systems, each of which provided additional safety when the patrolman was engaged in voice communications while driving in heavy traffic or conducting a high-speed chase were provided. Each system allowed drivers to transmit and receive voice communications without removing their hands from the steering wheel. One system utilized a small, lightweight, boom-mounted microphone that pivoted out of the way when not in use. Messages were received over the standard vehicle audio system speaker. The other system utilized a hearing-aid style ear unit containing both speaker and microphone. This system had low background noise and had the additional advantage of providing optional privacy if the standard audio system speaker were turned off. The ear unit was connected to the standard vehicle audio system by means of a wire, but a quick-disconnect plug was provided so that the device would offer minimum impediment to an officer's movement in exiting the vehicle. Either system was a selectable mode of operation, secondary to the standard vehicle audio system, and was operated by a foot switch.

d. Periscope rearview mirror. A periscope rearview mirror provided an unobstructed, wide-angle view to the rear. This device provided greatly improved rearward visibility which resulted in greater safety, particularly during merging and lane-changing maneuvers characteristic of emergency vehicle operation.

e. Seats and restraint systems. The standard bench seat or optional bucket seats available with factory vehicles have several drawbacks for police vehicle use. New seats were installed to provide improved safety, greater long-use comfort, and increased durability, and to permit rapid ingress and egress to/from the vehicle and more efficient utilization of front seat space.

One important safety feature of the new seat was the integral restraint system. The seat belt retractor was mounted on the seat rather than on the floor with a guide for the shoulder harness on the upper part of the seat frame. The webbing geometry was optimized to ensure proper placement of the restraints on the occupant from the standpoint of both comfort and safety, regardless of how the occupant chooses to adjust the seat. In addition, vehicle motion-sensitive retractors for both shoulder and lap portions of the system were used to prevent inadvertent lock-up of the belt while the occupant was trying to buckle-up or when he made a sudden movement and also in order to provide self-adjustment of the webbing. The resulting restraint system was one which provided protection in a crash situation, was comfortable over long periods, did not restrict movements to operate controls, and was easily and quickly put on and removed.

Another safety feature was the utilization of an integral seat-headrest frame of tubular steel which qualified as a roll bar. A clear ("see-through") vinyl cover, drawn tightly over the headrest frame, provided a resilient support for the head in the event of a rear-end collision but did not obstruct the driver's rearward vision.

Increased long-use comfort was provided by improved design of the seat back and seat pan. Proper posture control, a major factor in reducing fatigue, was ensured by providing the correct seat pan tilt angle and angle between the seat pan and the seat back. The fore/aft length of the seat pan cushion was sized to reduce pressures on the underside of the upper leg, which often restricts circulation, and both the seat pan and seat back cushions were designed to provide firm support. Instead of having raised sides, as do bucket seats, the seat pan cushion was flat. This design made it easier for the occupant to move his legs, to operate pedal controls and easier to get in and out of the seat. Sturdy construction and utilization of rugged upholstery fabrics were to provide durability. Finally, the utilization of individual front seats permitted the installation of a between-the-seat console, the control panel for the warning lights and siren.

3. Improved Productivity. The rapid advance in computer technology in the past few years, especially in terms of equipment cost and size, provided new capabilities for improved productivity. Development of the microprocessor made it physically possible to put a microcomputer in the police patrol car for a few hundred dollars.

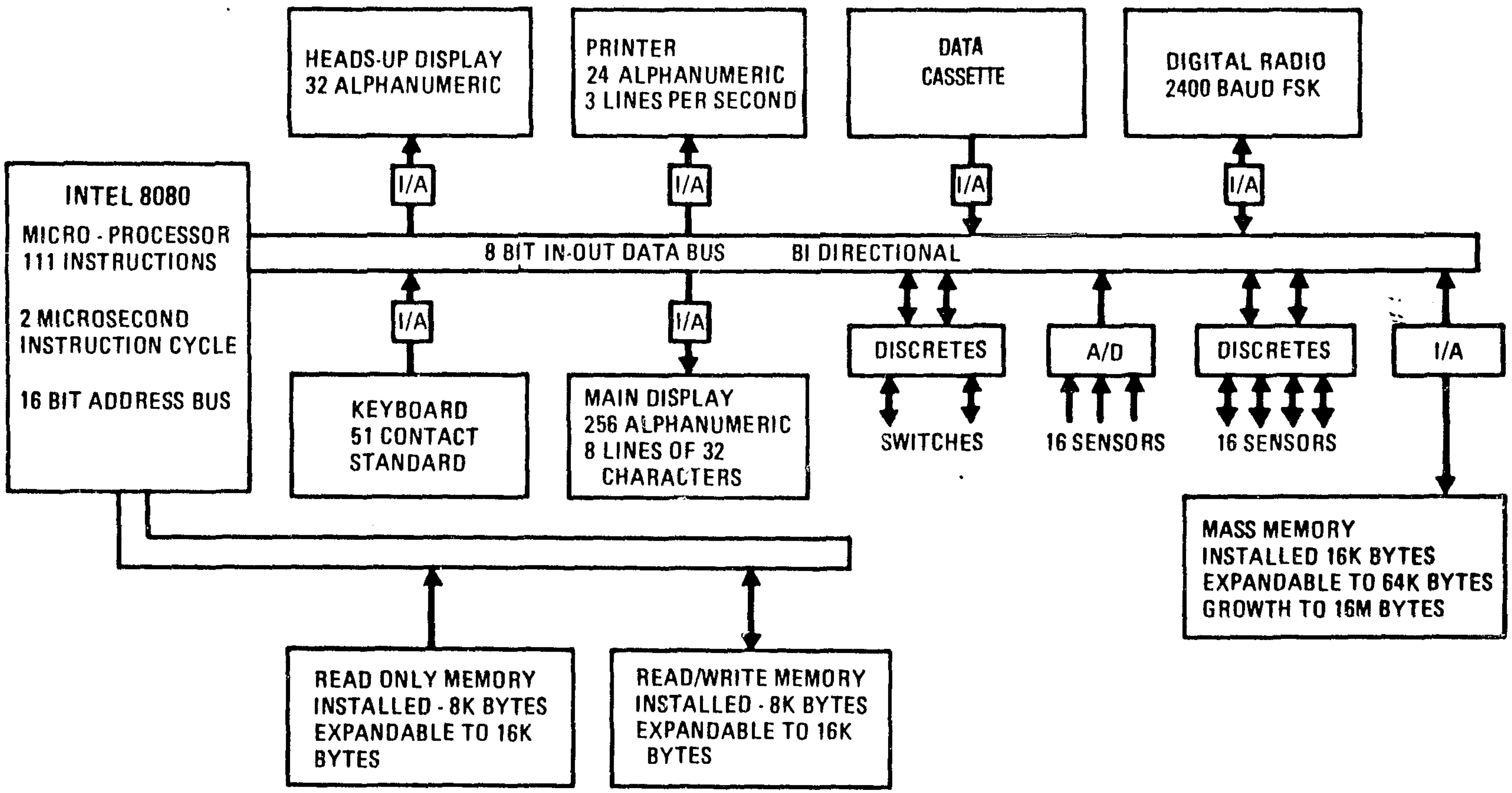

Figure 2-1. Data System Parameters

A digital communication and data system which utilized a digital terminal interconnected with a programmable microcomputer provided the base for a flexible integrated digital data system. This data system was an extension of commercially available mobile digital terminals, but the addition of the microcomputer made possible many capabilities not available with those systems. Commercially available mobile digital terminals are generally characterized by having a limited set of capabilities which are not expandable or adaptable, by having no general-purpose interfaces and by having no options on input/output devices. The programmable, general-purpose, computer-controlled prototype system, however, was capable of performing arbitrarily definable functions, giving it a wide range of capabilities which were both expandable and adaptable by means of software changes only. In addition, a general purpose interface philosophy allowed the utilization of a wide range of makes and types of input/output devices.

a. Data system components. A schematic block diagram of the prototype police car data system is shown in Figure 2-1. The data system components are described in the following sections.

(1) Microcomputer. The microcomputer controlled all peripheral equipment functions and provided timing and sequencing information for the entire data system. The heart of the microcomputer was an INTEL 8080 microprocessor which responded to peripheral service requests on a real-time interrupt basis and communicated with all peripherals through a common bidirectional bus. The microcomputer also contained a Programmable Read-Only Memory (PROM)

for program storage and a Random Access (Read and Write) Memory (RAM) for data storage. These memories, as installed in the prototype, contained 8192 bytes of storage in RAM and 12,188 bytes of PROM.

(2) Mass memory. A charge coupled device (CCD) serial access read and write memory used as an in-car data base, was intended primarily for storage of a local "hot sheet" of most-wanted vehicles and/or persons. Other types of information which might be stored in the in-car data base included roll call data, schedule and calendar information, training aids, procedures checklists, and formats for reports. The data base was loaded via a digital tape cassette prepared at the base station. Information in the data base could be retrieved in two ways. The data base could be searched in response to an inquiry, such as a stolen vehicle license check, or specific data could be recalled upon request. The prototype in-car check, or specific data could be recalled upon request. The prototype in-car data base provided 16,384 bytes of storage. The mass memory was packed in the same chassis as the microcomputer and was located in the trunk of the vehicle.

(3) Digital tape cassette and reader. A cassette reader for the digital tape cassettes utilized to load the in-car data base was installed within the dashboard facing on the passenger side of the prototype vehicle. The reader had a speed of approximately 32,000 bytes/minute and required about 30 seconds to fully load the in-car data base of 16,384 bytes in the prototype vehicle.

(4) Keyboard. The keyboard is the mechanism through which the patrolman "talks" to the data system and, via the digital communications channel, to the base station. In combination with a display device, it constituted a digital terminal. In most instances, the keyboard and display of a digital terminal are combined in a single package, but in the prototype system, they were packaged separately to permit greater flexibility in mounting. The keyboard was mounted on a slide-out tray centered under the dashboard and was accessible to either the driver or a passenger in the front seat.

The keyboard selected had a conventional 51-key typewriter layout which provided the standard alphanumeric and control characters. In addition, some alphabetic keys were labeled and interpreted as function keys and keys 1-9 were interpreted as ten-code status keys when the data system was in selected operational modes.

(5) Main display. The main display was used for viewing data entered via the keyboard, information received through the digital communications channel, retrieved from the in-car data base, or generated by the microcomputer. Together with the keyboard, it constituted a digital terminal. The main display selected for use in the prototype system was a plasma array panel with a display capacity of 256 alphanumeric characters in eight lines of 32 characters each. The bottom line of the display was reserved for diagnostics indicating communications status. The display panel was packaged separately from its drive circuit, allowing a flat configuration which was mounted on the dashboard facing panel above the keyboard. This display could be viewed by either the driver or passenger, but in order to do so the driver had to take his eyes off the road.

(6) Heads-up display. A heads-up display mounted on the cowl behind the steering wheel, in the driver's field of view, provided messages to the driver while the road ahead remained in his peripheral vision. This display was intended to alert the driver to an incoming message by displaying the first 32 characters of the message and to alert the driver to potentially dangerous situations by displaying messages generated by the microcomputer when the vehicle diagnostics system detects an out-of-tolerance reading from one of its sensors. The heads-up display installed in the prototype system was a light-emitting-diode (LED) display with a capacity of 32 characters in a single line.

(7) Printer. The printer had the capability of providing a hard copy of any data stored in the main display buffer. Thus, the officer could use it to copy data entered by him via the keyboard, a message received from the base station, or data retrieved from the in-car data base. A thermal printer with a capability of 16 characters per line and a speed of 3 lines per second met the requirements of small size, necessary for mounting behind the console between the front seats.

(8) Hand-held andio/digital terminal. The capability to use the police car data and audio systems from outside the car was provided by a hand-held, man-portable, audio/digital terminal. The hand-held terminal provided freedom to be away from the vehicle, while maintaining voice and digital communication capabilities. The terminal utilized a miniaturized digital terminal, with a built-in modem, in conjunction with a personal equipment voice radio to transmit and receive both voice and digital messages on a single channel. The terminal communicated with a dedicated modem and radio in the vehicle.

The digital terminal had a self-scan, full alphanumeric display with 16 character positions, which was capable of scanning a full 64-character message from right to left across the display. A recall feature permitted the complete message to be scanned again. The terminal also had a telephone type keyboard with full alphanumeric entry capability as well as several function keys which included: recall, backspace, space, clear, roll, acknowledge, and five transmit functions. These transmit functions provided capabilities for making data base inquiries, reporting the officer's status, routing messages to the dispatcher, requesting pending messages to the officer and sending an "officer needs help" message to the dispatcher.

(9) Voice tape recorder. A cassette voice tape recorder, installed on a slide-out tray within the dashboard facing on the passenger side, provided the capability to record field interviews with victims, witnesses, or suspects via the hand-held terminal or an in-car microphone. It also permitted recording of voice radio transmissions.

(b) Data system operations. The following operations could be performed by the data system: prompted data input, digital communications, data storage and retrieval, and monitoring of vehicle sensors. These operations are discussed in the following sections.

(1) Prompted data input. One important feature of the data system was the use of prompters to facilitate the input of data to the system. To initiate input, the operator pressed one of the clearly marked function keys, and the microcomputer program was automatically activated for the function corresponding to the pressed key. A code identifying the selected function

and the first data to be input appeared on the main display. At this point, the operator had the option of entering the requested information or leaving a blank and requesting the prompter for the next input quantity. In either case, the operator terminated the response to a prompter and requested the next prompter by pressing the "period"(.) key. In this fashion, the operator interacted with the microcomputer, via the keyboard and main display, until the input function had been completed or until all desired data had been entered. At this point, he could press the "print" key to activate the printer and obtain a hard copy of the input data, and/or he could transmit the data to the base station.

Input functions were provided for signing on, message composing, initiating data base inquiries, and preparing reports. The sign-on function provided a means for notifying the dispatcher that the car was going into service, and, more importantly, it provided a means for controlling access to the law enforcement data base. The operator signed on by entering identification information such as his name, badge number, and car number, and transmitting these data to a dispatcher. The dispatcher verified that the operator was authorized to access the data base and must manually acknowledge the sign-on in order to permit the in-car data base to be loaded via the data tape cassette and to permit the data base inquiries.

Input functions corresponding to several commonly used reports, such as field interview and motor vehicle theft reports, were provided. Using one of these functions, an officer could prepare a report, in a format corresponding to the standard form for the report, as he is obtaining the information in the field. The completed report could then be transmitted directly to the base station. The officer, utilizing the in-car printer, could retain a hard copy of the report for his personal records.

The prompted input capability provided a simple method for encouraging accuracy and completness and for ensuring proper formatting in the input operation. In addition, input functions could be changed, deleted, or added to by means of software changes.

(2) Message handling. The microcomputer controlled all aspects of the digital communications system, ensuring orderly conduct of communications, fulfillment of protocol requirements, and verification of accurate transmission. Following the input of an outgoing message via the keyboard in response to appropriate functional promptors, transmission was initiated via the transmit key. The microcomputer automatically appended certain required data, such as a message number and an identification code for the vehicle, to the message. Messages from the base station to the vehicle also contained such codes and checks for transmission errors.

(3) Monitoring of vehicle sensors. The sensors described in the section on vehicle diagnostics provided inputs to the data system microcomputer. Out-of-limit conditions were automatically indicated on the heads-up display under microprocessor control and initiated a vehicle condition report transmission to the base station. It was also possible at any time to route a vehicle condition report either to an in-car display or to the base station.

B. Development, Fabrication, Bench Test, and Integration

In order to fully check out the data system, it was necessary to build a simulated base station. This consisted of a computer terminal, microcomputer, tape recorder, and a UHF base station transceiver. The two transceivers were first interconnected via coaxial cable with a large attenuation introduced to simulate transmission path losses. After the vehicle installation was completed, the simulated base station was transferred to a van, equipped with a motor generator and air conditioning. This mobility made it possible to move the prototype police car and van to various locations, both in the Washington, D. C., metropolitan area and elsewhere for on-the-air tests and demonstrations. Two systems were produced to facilitate the development cycle and also to make it possible to perform trouble shooting and repairs on the bench by interchanging boxes between the vehicle and bench systems if failure or malfunction occurred in the car.

The philosophy governing the design of the prototype system was that functionally it would be equivalent to the planned follow-on 20-car field test system which was to be tested in New Orleans and Dallas. However, in the interests of expediency, the design of the trunk-mounted components did not need to be as small physically as the final design planned for the field test. The power supply in particular was designed with bulky off-the-shelf components, making it several times as large as an integrated design.

The integration of all components and subsystems into the prototype vehicle was performed by Atlantic Research Corporation, a sub-contractor; tasks included:

- Preparing layout drawings and sketches for all equipment;
- Fabricating or purchasing all special fittings, brackets, trays, shelves, etc. as required for proper installation;
- Preparation of wiring sheets for interconnection of all equipment and fabrication of all cabling;
- Installation of all cabling in and under the car;
- Cutting holes in dashboard, body, bulkheads, fenders, roof, trunk deck, etc. as required for installation of components and making cable runs;
- Design and fabrication of the light/siren control console located between the front seats;
- Replacing vehicle-supplied alternator with a high-current (130-ampere) alternator;
- Moving existing vehicle components as necessary to accommodate installation of new components;
- Installation of all system components into the vehicle (with exceptions noted;
- Checkout of all safety/economy equipment items; and
- Cooperating with the Telecommunications System Division of Atlantic Research in checkout of the data system.

A complete list of all equipment installed in the car is given in Table 2-1. Physical dimensions, weight, manufacturer, installation location, and power requirements are shown.

To facilitate installation of equipment in the trunk, the spare tire was removed and a sheet of plywood, covered with an aluminum plate, was mounted to provide a flat, grounded mounting plane.

An overall view (Figure 2-2) of the car from the front shows the Code 3 light bar, periscope rearview mirror, and vehicle antennas. The side cowl antenna worked with the citizens band radio and the center-of-the-roof antenna with the 450 MHz data transceiver. The rear side view of the car is shown in Figure 2-3. The two siren/public address speaker horns can be seen underneath the right-hand side of the light bar. Figure 2-4 is a closeup view of the Code 3 light bar and shows the clear covers over the rotating lights in place. The side-facing alley lights are shown, and the remotely controlled spotlight is flanked by the fixed fore and aft lights. A detailed view of the left side of the light bar, shown in Figure 2-5, shows the waterproof aircraft-type connector used to complete the light bar circuits to the vehicle wiring. Use of this connector facilitated interchange of the Code 3 light bar and the alternate bar equipped with Whelen strobe lights.

In the rear view of the car, Figure 2-6, the trunk ventilating exhaust duct will be noted just to the left of the license plate. The trunk was ventilated, to remove equipment heat, by a fan that moved air from the passenger compartment to the trunk. The air was then exhausted via the ventilating duct.

Table 2-1. Prototype Vehicle Equipment

	Component	Weight	Dimensions H X W X D (in.)	Mfg.	Part No.	Install. Loc.	Power Requirements +12V	-12V	5V	Misc.
1	Main Display & Panel Driver	9 lbs	8 x 12 x 2½	Panel-ARC Burroughs	Modified by ARC Model BD5K0332-201	D	-	0.25	4	-250V, 0.12 +30V, 0.01
2	Main Display Elec.	3 lbs	6 x 11 x 5	Burroughs	Same as above, both part of package	UD	Included in above			
3	Heads-Up Display	1 lb	2½ x 20 x 2½	ARC.	None	D	-	0.04	1.7	-
4	Keyboard	1lb,8oz	1½ x 13 x 7	Cherry Elec. Products	B70-60AA (Modified by ARC)	UD	-	-	0.35	-
5	Printer	10 lbs	5½ x 5 x 10½	Kustom Data Communications, Inc.	MPT-10	BS	3, with peaks to 9	-	-	-
6	Printer Interface	1 lb	2 x 7 x 5	ARC	None	US	-	0.05	0.2	-
7	Digital Cassette	3 lb,8 oz	4 x 6 x 8	Sycor Co.	Model 135 (Modified by ARC)	D	0.1	0.15	0.5	24V, 1, with peaks to 3
8	Audio Recorder	3 lb,8 oz	3 x 5 x 10	Panasonic	Model RQ309AS	D	0.5, conv. to 9V	-	-	-
9	Siren Recorder	3 lb, 8 oz	3 x 5 x 10	Panasonic	Model RQ309AS	T	0.5, convert to 9V	-	-	-
10	Microprocessor and Memory	8 lbs	8 x 19 1/8 x 11 1/8	ARC	None	T	1	2.5	9	.5V, 0.3
11	Analog/Digital Conv.	3 lbs	3 x 10 x 12	ARC	None	T	-	-	0.35	-
12	Signal Conditioner	3 lbs	3 x 10 x 12	ARC	None	T	0.3	0.3	-	-
13	Mobile Digital Radio & Antenna	25 lbs	3.25x15x23.75	Motorola	Model No. T31RTA3003BK	T&R	10.5Tx 2.6Rx	-	-	-

Location Legend: D - Dashboard; UD - Under Dashboard; BS - Between Front Seats; US - Under Rear Seats; T - Trunk; R - Roof Mount; UH - Under Hood; F - Floor; W - Wheel Mount; C - In Console

Table 2-1. (Continued)

	Component	Weight	Dimensions H X W X D (in.)	Mfg.	Part No.	Install. Loc.	Power Requirements +12V	-12V	5V	Misc.
14	Communications Controller (Digital	5 lbs	3 x 10 x 12	ARC	None	T	0.3	0.03	0.3	-
15	Data System Battery	30 lbs	8 x 8 x 16 1/2	J. C. Penny	Group 27	T	-	-	-	-
16	Main Display Power Supply	20 lbs	7x5½ x 11 3/4	Burroughs	BDS40832-PS1	T	-	-	-	115 AC, 2 max.
17	DC/AC Inverter	55 lbs	7 x 19 x 13	Topaz Elec. Co.	500-GP12-60-115	T	50 max 25 nom	-	-	-
18	Hand Held Terminal	2 lbs	-	EMS, Inc.	DAT 4004	D	-	-	-	-
19	Wide Angle Rearview System	15 lbs	18 x 8 x 5	Para-Vue	None	R	-	-	-	-
20	Console (including Audio Control Panel	5 lbs	9 x 8 x 14	ARC	None	BS		(See No. 49)		
21	Motor Minder Gauge	8 oz	3 x 4 x 4	Steward-Warner Corp.	82400	D	0.5	-	-	-
22	Multiple Spark Discharge	8 oz	2¼ x 8½ x 4	Autotronic Controls	MSD-2	UH	6	-	-	-
23	Ear Comm Foot Switch	2 oz	3 x 3 x 1	Realistic - Radio Shack	44610	F	-	-	-	-
24	Oil Pressure Sensor	2 oz	½ x ½ x 1½	Stewart-Warner	279A	UH	Neg.	-	-	-
25	Oil Temp. Sensor	2 oz	½ x ½ x 1½	Stewart-Warner	280EE	UH	Neg.	-	-	-
26	Coolant Temp. Sensor	2 oz	½ x ½ x 1½	Stewart-Warner	362 AH	UH	Neg.	-	-	-
27	Exhaust Temp. Sensor	2 oz	½ x ½ x 1½	Hewitt Co.	Pyrometer	Exhaust Pipe	Neg.	-	-	-
28	Transmission Oil Temp. Sensor	2 oz	½ x ½ x 1½	Stewart-Warner	280EE	UH	Neg.	-	-	-

Table 2-1. (Continued)

	Component	Weight	Dimensions H X W X D (In.)	Mfg.	Part No.	Install. Loc.	Power Requirements +12V	-12V	5V	Misc.
29	Speed Sensor	2 oz	½ x 1 x 3	Flo-Scan	P/O MPG Meter	Speed Cable	Neg.	-	-	-
30	Tachometer	2 oz	1 x 1½ x 1	Stewart-Warner	819891	UH	Neg.	-	-	-
31	Fuel Flow Sensor	2 oz	1 x 1 x 3	Flo Scan	255-PB-15	UH	0.27	-	-	-
32	Fuel Level	2 oz	-	Exist. Gauge	-	Exist. Gauge	-	-	-	-
33	Battery Voltage Sensor	2 oz	1 x 1 x 1	ARC	None	UH	Neg.	-	-	-
34	CO Monitor	3 lbs	5 x 8 x 4	E. D. Bullard	Series 1000	T	0.5	-	-	-
35	Low Tire Press. Sensor Control Box - 8 oz 5 Wheels Sensors-2 oz.ea.	18 oz	2x4x6(control box)	Jaeger Co.	No part number	W&T	1.0	-	-	-
36	Low Coolant Sensor	4 oz	1½ x 1½ x 3½	Robert Shaw Controls Co.	Model 613NLG	UH	Neg.	-	-	-
37	Brake Wear Sensor	2 oz	-	-	-	W	Neg.	-	-	-
38	Anti-Skid Brake Systems			Bendix Corp.						
	a. Canister-3 cans at 16 lbs.	48 lbs	7(diam)x8.5(length)		E2761980	UH&T	0.15 with	-	-	-
	b. Electronics Control	2 lbs	3.5 x 5 x 8.5		E2761760	T	peaks 9.18	-	-	-
39	Engine On/Off		-	-	-	-	-	-	-	-
40	Driver In/Out of Seat		-	-	-	-	-	-	-	-
41	Code 3 Lightbar and Brackets	80 lbs	19 x 55 x 9	Code 3 Co.	Code 3	R	60.5	-	-	-
42	Strobe Light Bar and Brackets	70 lbs	17 x 55 x 6	Whelen Engr. Co.	Model 2200	R	36	-	-	-
43	130 Amp Alternator	8 lbs	9 x 5½ x 6	Leece Neville	7705AA	UH	-	-	-	-

Table 2-1. (Continued)

	Component	Weight	Dimensions H X W X D (in.)	Mfg.	Part No.		Power Requirements			
44	130 Amp Regulator	1 lb	1½ x 2 x 3	Leece Neville	5078RB	UH	-	-	-	-
45	Battery Isolator	5 lbs	3 x 7 x 5	Sure Power Products Co.	1302	UH	-	-	-	-
46	Peripheral Interface	8 lbs	2 x 14 x 4½	ARC	None	D	-	-	0.7	-
47	CB Radio/Antenna	2 lbs	2 x 3½ x 4	Realistic-Radio Shack	Model TRC-9A	D	1.5	-	-	-
48	Strobe Light - Power Supply	5 lbs	2 units 3½ x 5 x 5	Wheelen Engr. Co.		T	Included In No. 42			
49	Audio Communications Controller	5 lbs	4 x 5 x 4¼	ARC	None	C	0.2	-	0.5	-
50	Hand-Held Radio	3 lbs	-	-	-	T	-	-	-	-
51	Siren/PA Amplifier	3 lbs	3 x 5 x 4½	Dunbar Nunn	Model 80	D	10	-	-	-
52	Light Bar Control Head Accessory Switchhead	2 oz	4 x 5 x 1¼	Dunbarr Nunn	Model 480 Model A	C	0.1 0.1	- -	- -	- -
53	Flow Scan MPG	3 oz	3 x 4 x 4	Flo-Scan Instr. Co.	Model 10A	D	See No. 29 and 31			
54	Flow Scan Totalizer	½ lb	3 x 4 x 1.6	Flo-Scan	None	T	0.5	-	-	-
55	Ear Comm. Hands Free Comm. Unit	2 oz	½ x ½ x 2½	Lear Siegler	Model 1106	C	Internal Battery			
56	Main Power Supply-Data System	50 lbs	7 x 19 x 6	ARC	None	T	-	-	-	115 AC, 4.0
57	Discrete I/O (2 each)	2 lbs	2 x 7 x 5	ARC	None	T	0.2	-	0.2	-
58	Headlight Flasher	8 oz	1 x 1 x 1	Dunbar Nunn	Unitrol Model 13		2			
59	Strobe Light Relay Box for Power Supply	1 lb	2 x 7 x 5	ARC	None	T	0.1	-	-	-
60	Front Seats	35 lbs	45 x 19 x 19	Man Factors	Bucket Seats	-	-	-	-	-

Figure 2-2. Overall View of Police Car

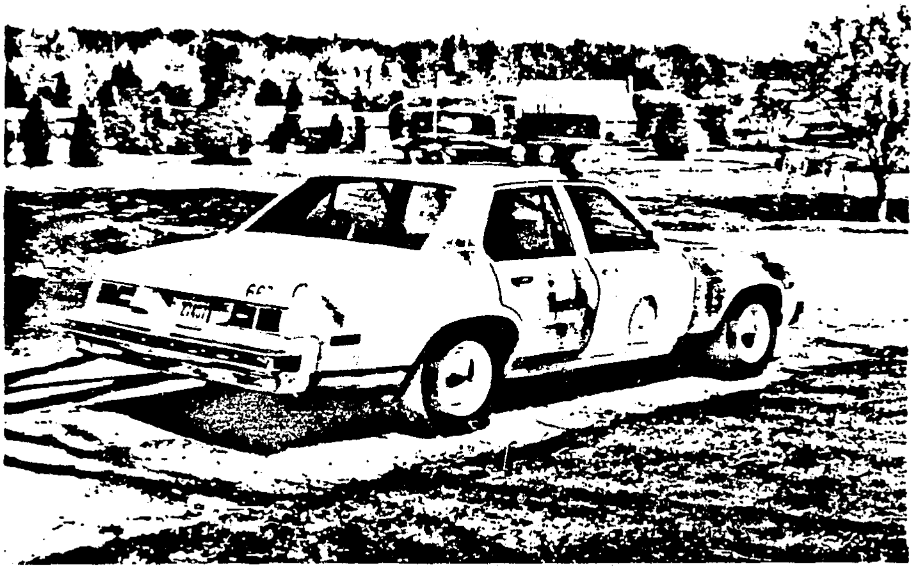

Figure 2-3. Rear Side View of Police Car

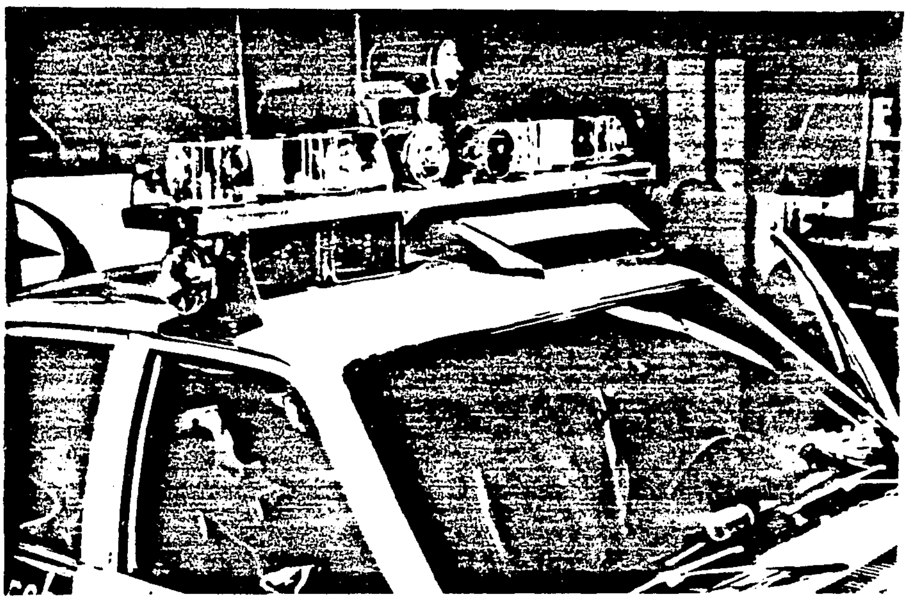

Figure 2-4. Closeup View of Code 3 Light Bar

Figure 2-5. Left Side of the Light Bar

Figure 2-6. Rear View of the Police Car

Figure 2-7. The Police Car Data System

Figure 2-7 shows the police car data system. The main computer display is cut into the center, the slide-out keyboard is underneath, the digital tape cassetts is just under the right-hand end of the main display, with the audio recorder cut into the former map compartment space at the far right. In the center foreground is the light/siren/public address control console. The miles-per-gallon gauge is on top of the dashboard to the right of the steering wheel. An oblique view of the front-seat area (Figure 2-8) shows the heads-up display above the dashboard (top, left of center). The thick, carpet-covered cable on the floor, next to the transmission hump, is the main interconnecting cable between the dashboard system components and the equipment installed in the trunk. The heads-up display is again shown in Figure 2-9. In this figure, the earcom transducer (microphone/receiver) is shown as worn by the driver, and the control unit for the citizens band radio is above the driver's right knee.

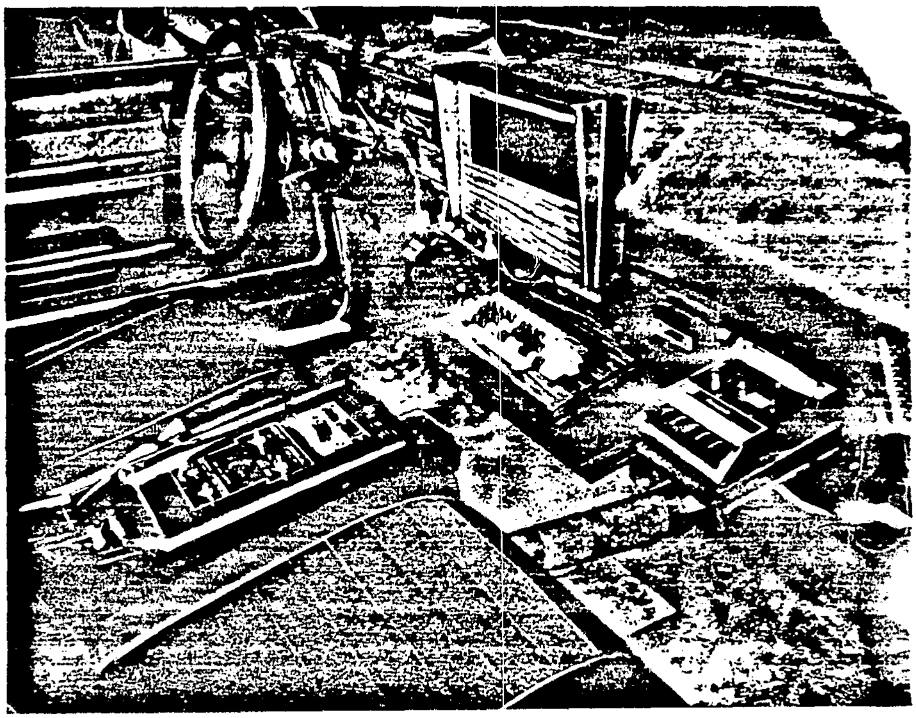

Figure 2-8. Oblique View of Front Seat Area

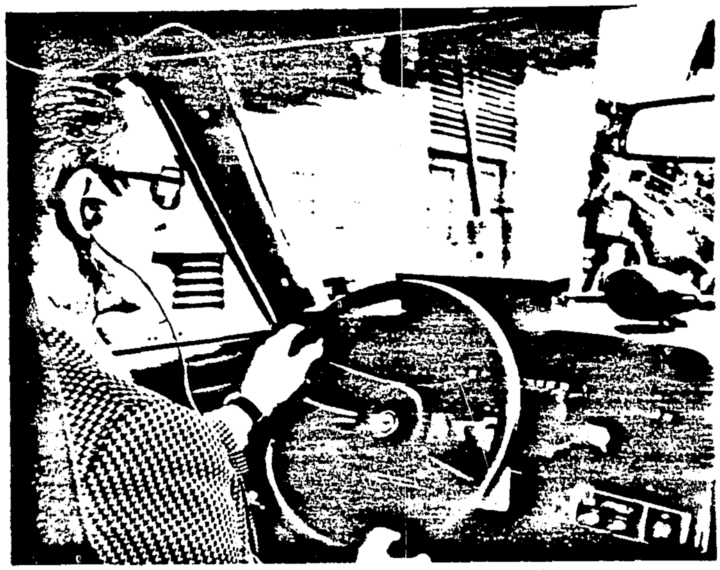

Figure 2-9. Earcom Transducer and Citizens Band Radio

The front seats (Figure 2-10), manufactured by Man Factors, have a plastic head rest slipped over the roll bar frame mounted on top of the seats. The control console is visible between the seats. A close-up of this light/siren/public address control console is shown in Figure 2-11. Radio and public address microphones clip to the front of the console.

The engine compartment is shown in Figure 2-12. The 130-ampere Leece-Neville generator is to the left. Voltage regulator and relay is in the center between the fan shroud and the carburetor air cleaner. The MSD (multiple-spark discharge) unit is mounted to the right, partially above the air conditioning compressor. Mounted along the inside of the left fender in the engine compartment are the three hydraulic actuators for the four-wheel antilock brake system (Figure 2-13). Each front wheel has an individual actuator. The rear wheels are controlled by a single actuator.

A partial view of the trunk is in Figure 2-14. The data system storage battery is on the left, and the Motorola transceiver is in the foreground. The large power supply behind the transceiver is the dc-ac inverter. To the right and behind this unit, the microcomputer is partially visible. In front of the microcomputer is the power supply for the main display. Power supplies for the data system are in the right foreground. The siren tape recorder is between the transceiver and the dc-ac inverter, and the power supplies for the strobe light bar are partially visible behind the battery. Not visible in Figure 2-14 are the antilock brake electronics and tire pressure electronics. The carbon monoxide monitor electronics box which is located in the trunk is shown in Figure 2-15. The cylindrical sensor head in the foreground of this figure is located in the driver/passenger compartment. Figure 2-16 shows a hand-held terminal.

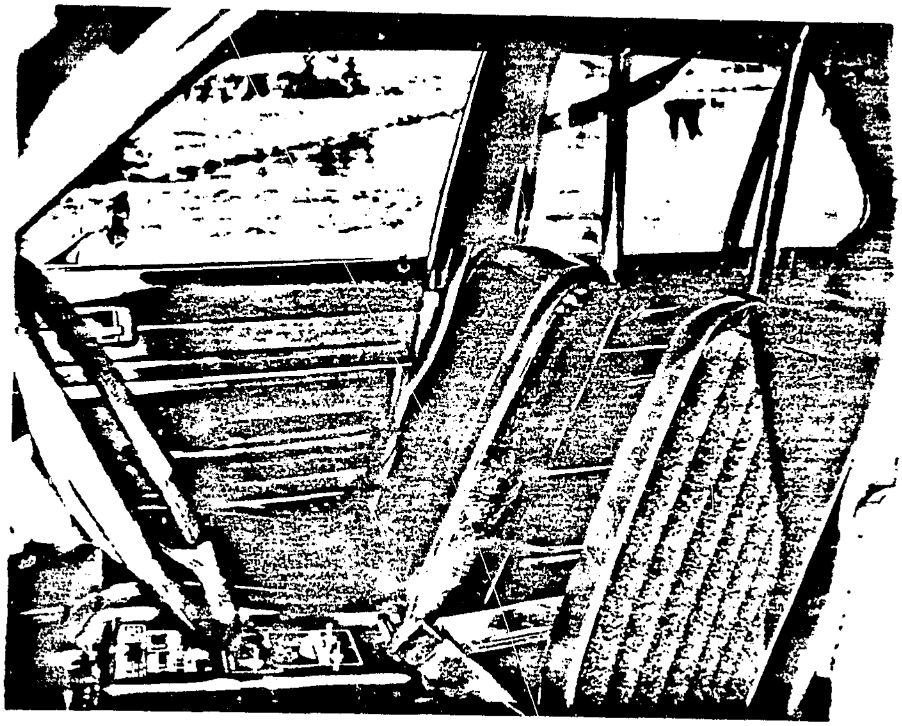

Figure 2-10. Front Seats and Control Console

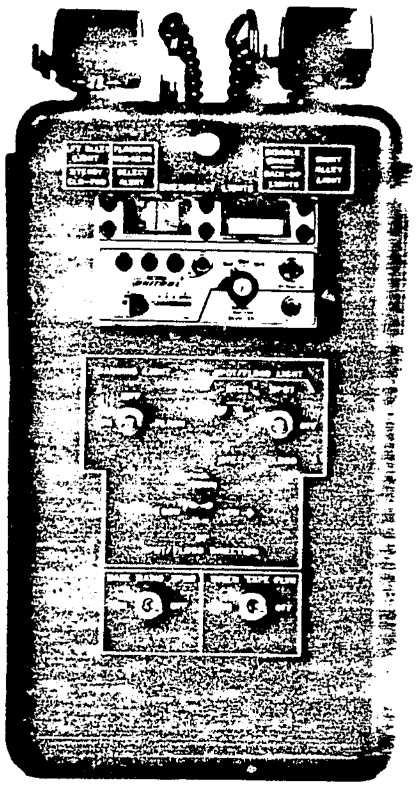

Figure 2-11. The Light/Siren/Public Address System Control Console

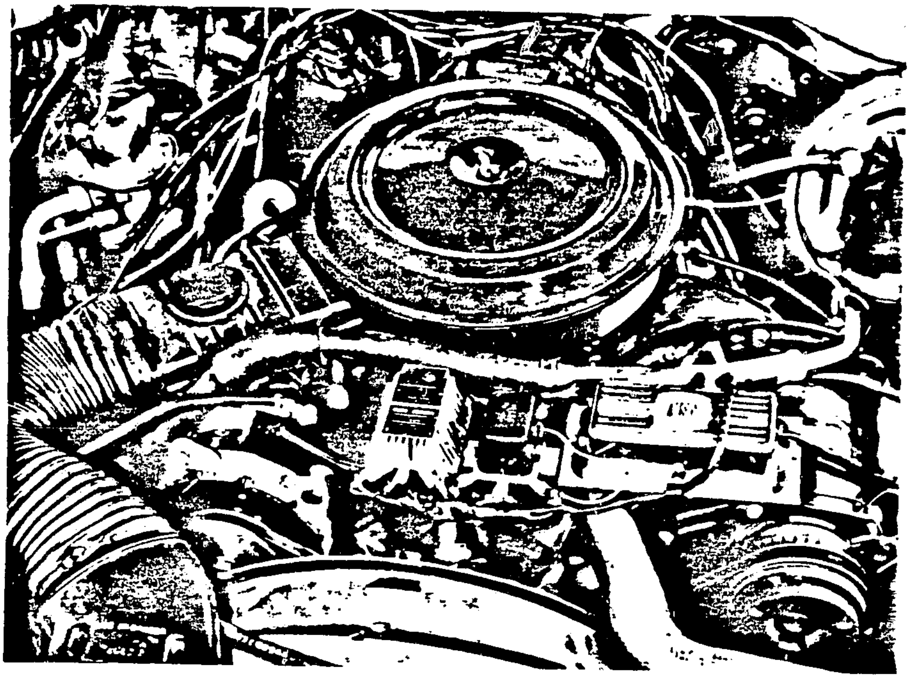

Figure 2-12. Engine Compartment

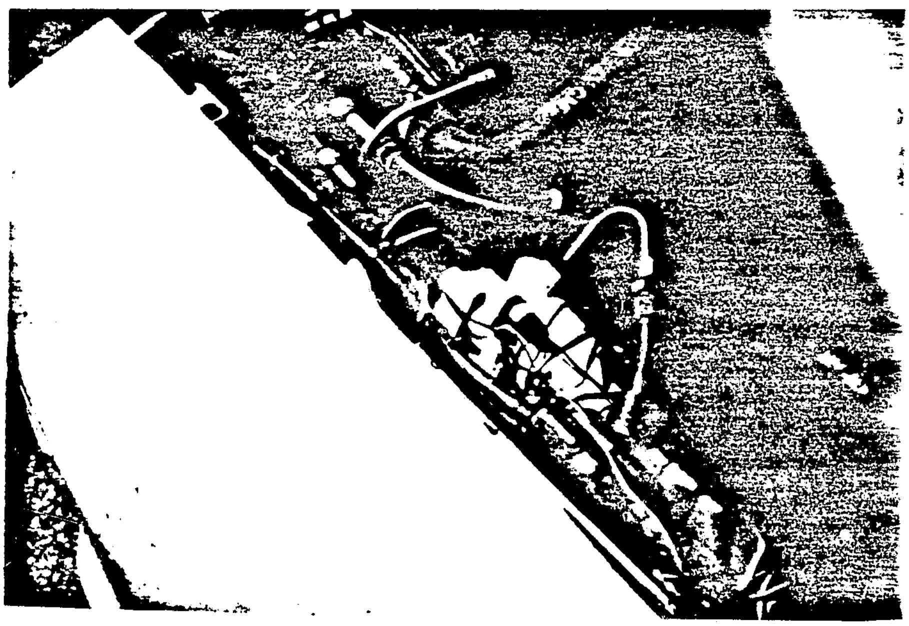

Figure 2-13. Hydraulic Actuators for the Four-Wheel Antilock Brake System

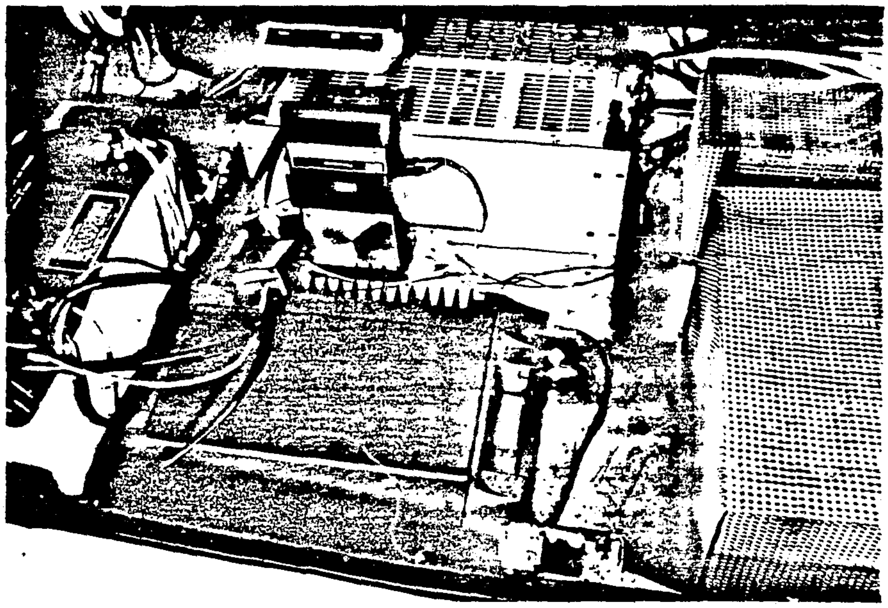

Figure 2-14. Partial View of Trunk Showing Power Supplies

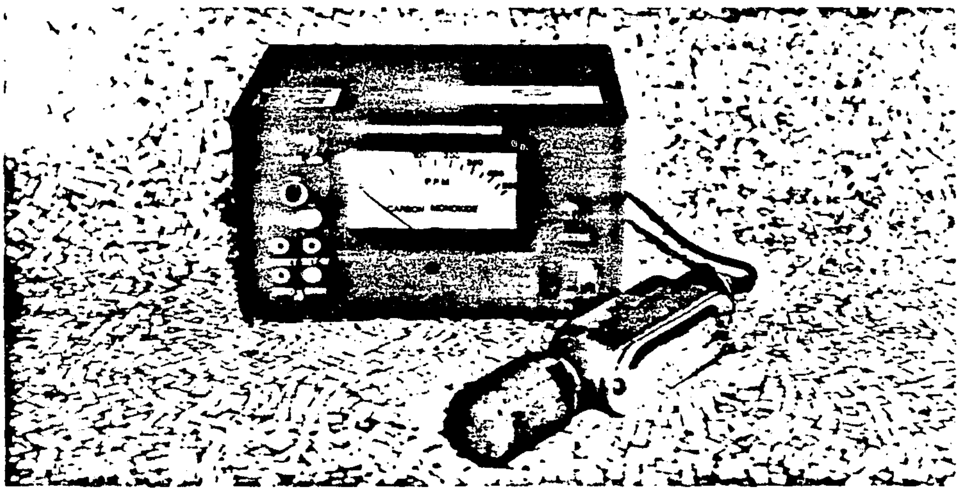

Figure 2-15. Carbon Monoxide Monitor and Sensor Head

Figure 2-16. Hand-Held Terminal

C. Demonstrations and Films

1. Demonstrations

The prototype police patrol car was completed in mid-March of 1976 and was immediately shipped to New Orleans, Louisiana, to be exhibited and demonstrated at a meeting of the Police Patrol Car System Improvements Advisory Council which was convened for this showing. Following this meeting, the car was driven to Dallas, Texas, and shown to police and other city officials. The vehicle was then returned to Washington, D. C.

On April 6, 1976, the Aerospace Corporation provided a demonstration of the prototype vehicle to the Deputy Attorney General, U.S. Department of Justice, Mr. Tyler. A briefing on the program was presented in conjunction with the vehicle showing. At the request of the U.S. Department of Justice, Aerospace supported an exhibition of the car at a national press conference held on April 21, 1976. In May 1976, the car was driven to Philadelphia, Pennsylvania, where it was shown to attendees at the International Project SEARCH Symposium. The car was again exhibited and demonstrated at the convention of the International Association of Chiefs of Police, held in Miami Beach, Florida, during the latter part of September 1976.

Following these demonstrations the car was held in readiness in the Washington, D. C., area for occasional showing to interested parties as requested by the Law Enforcement Assistance Administration.

2. Films

Three films were produced during the course of the police car program. They were:

- ° Police patrol car training film--16 mm sound and color
- ° Antilock brake tests--16 mm sound and color
- ° Vehicle equipment installation--16 mm silent and color

a. Training film. The purpose of making this film was to provide all participating personnel--police patrol officers, dispatchers, supervisors, vehicle maintenance, and upper police management--with a comprehensive overview of how the vehicle functioned with all of the added components and subsystems. Work on this 15 minute film started in February 1976 with the assistance of the Metropolitan Washington, D.C. Police Force, showing the improved police patrol car in simulated field operations and depicting typical use of the various subsystems. The title of this film is "In Pursuit of an Improved Police Patrol Car."

b. Antilock brake test film. A second film produced for the program was entitled "In Pursuit of an Improved Police Patrol Car - Antilock Brake Tests." This 14 minute film shows vehicle operation on several types of pavement with the antilock brake system operative and inoperative. The improvements in stopping distance and handling performance afforded by antilock brakes in emergency stops are clearly demonstrated.

The raw film footage used in this film was largely obtained as a by-product of the tests run by Bendix Corporation and Kelsey-Hayes at their skid pad test facilities in Indiana and Florida. The contracts with these firms included film shooting as a part of the data to be acquired.

c. Vehicle integration film. A requirement in the contract with Atlantic Research Corporation was that the various steps and phases of the vehicle integration process be filmed. No sound was required, and rough hand titles written on a slate were acceptable. The intent was to preserve a record of the build-up of the vehicle as a possible aid in the design/development on the 20-car vehicle integration contract which was to have followed.

The scenes show installation and checkout of all major items of equipment, including communications and safety/economy items. "Before and after" shots illustrate the numerous vehicle modifications.

The film has some 25 scenes; running time is approximately 25 minutes.

D. Prototype Vehicle Findings and Conclusions

The prototype vehicle demonstrated the feasibility of implementing virtually all of the safety, economy, and utility concepts developed over the course of the program. This section details the specific findings related to the practicality and suggested future directions of subsystem implementations. Of course, these findings do not relate to the ultimate utility or acceptance of specific systems. This can only be achieved through thorough field testing by the police community. The prototype vehicle addressed only initial implementation methods and techniques.

1. Economy concepts

a. Compact car. The prototype vehicle proved that a compact vehicle, the Chevrolet Nova, has adequate space to install all of the safety, economy, and utility devices described in the system design section. This was accomplished without sacrificing any usable space within the passenger compartment. Although the trunk was, in fact, filled with electronic equipment, much of the space and weight of the total equipment in the trunk can be eliminated by tailoring the power supplies to their specific functions. The power supplies used were mass-produced, general purpose units designed primarily for stationary installations.

b. Vehicle diagnostics. Vehicle health and economy sensors performed their functions generally as expected. The vacuum gauge, installed on the dashboard and available as an original equipment option performed its function well.

The low tire pressure sensor system was effective operationally but is relatively expensive to implement. Further development in low-cost effective tire pressure sensing devices is indicated.

c. Multiple-spark-discharge ignition system. The particular device chosen for this concept was integrated without difficulty but was prone to failure while the vehicle was in operation. Its effectiveness was not fully evaluated. Owing also to its high initial cost, this device did not demonstrate any substantive improvement in vehicle operating economics.

2. Safety concepts

a. Antilock brakes. A three-channel antilock brake system was successfully installed and tested on the prototype vehicle.

b. Emergency warning system. The emergency warning system was successfully implemented as two independent subsystems using both revolving lights and strobe lights.

c. <u>Hands-free voice communication systems</u>. These were not fully integrated into the audio system due to programmatic difficulties, but no problems were anticipated when the voice radio was mounted in the vehicle. However, some installation and usage problems were anticipated if an officer uses only a personal equipment radio. In those cases where officers must hook their radios as well as themselves into the system, rapid ingress and egress, especially under stressful situations, could be hampered by the additional necessary disconnect/connect functions.

d. <u>Periscope rearview mirror</u>. This device was successfully installed on the prototype vehicle. No unusual problems were associated with the implementation. The protrusion of the rearward facing mirror through the roof necessitated a somewhat higher than normal mounting bracket for the warning lights, speakers, etc.

e. <u>Seats and restraint systems</u>. The seats and associated restraint system are believed to be a major improvement over the original equipment supplied. The seats have proved to be very comfortable over extended periods of driving. Frequently, initial reaction focused on the firmness of the seats. This is believed to be an important factor in improving long-term comfort and durability.

3. <u>Utility concepts</u>

The data system components, with few exceptions, proved to be completely satisfactory. Prompted inputs, digital transmissions and simulated data base inquiries were performed readily and with ease. Mass memory loading and local data base inquiry performed as expected.

The only significant item where further effort was indicated is in the brightness of the main display. The plasma display selected for this purpose had several highly recommendable features. It was small, thin, and lightweight and readily interfaced to a microprocessor. However, during high ambient light conditions, the display became very difficult to read particularly when the sun shone directly on the display. A satisfactory solution was found in a specially designed cathode-ray tube type display manufactured by E-Systems.

If any improvements were indicated in the prototype choice of printer, it would be to select one that produced a longer line on a wide paper format. The prototype used 24 characters per line. But 37 characters per line or more appear highly desirable.

The hand-held audio/digital terminal was successfully implemented. The remote digital capability to summon emergency aid was particularly promosing. A problem was the rather large size of the combined unit that includes the terminal, batteries, and two-way radio. Battery life was quite short due to the high power requirements of the display. Future versions could be expected to be smaller and much lighter through the use of complimentary mental oxide semiconductor (CMOS) logic circuitry and LCDs.

4. Antilock brakes

The following conclusions were derived from the series of tests and analyses conducted for the antilock brakes.

- Four-wheel antilock brakes provide a significant improvement in stopping distance and handling on road surfaces with low skid numbers, corresponding to wet, icy, snow-covered, or wet and oil film-covered pavements.
- Stopping performance with antilock brakes on dry asphalt is about equivalent to locked-wheel stops. However, loss of rubber and tire damage is prevented with the antilock system on.
- On split coefficient stops, the three-channel system performance, with independent front-wheel control, was superior to common front-wheel control.
- An exception to stopping distance reduction with antilock brakes occurred when stops were made on loose gravel. Here locked-wheel stops were made in a shorter distance.
- Full vehicle control, during lane changes, was maintained with four-wheel antilock brake systems.
- Full vehicle control can be maintained when stopping on a curve with four-wheel antilock brake systems (at least for tested speed limit of 25 miles per hour).
- Performance of the hydraulically powered and vacuum-powered systems was essentially the same.
- The systems were not susceptible to interference from strong radio frequency fields.
- Design of the systems is such that they may be expected to fail-safe if a malfunction occurs.

III. Field Test Program

A. Planning and Procurement

Planning for the Field Test Phase of the program proceeded concurrently with the prototype vehicle development and test. Following selection of New Orleans and Dallas as the field test sites, close liaison was established with both of these cities by The Aerospace Corporation Program Management. Individuals responsible for program coordination in each cooperating police department were identified, and visits were made by the prime contractor, Aerospace, to each city to acquire information as to police operations and data processing facilities.

A comprehensive Memorandum of Understanding was drafted by Aerospace in coordination with each of the participating cities and the LEAA Project Manager. This memorandum specified the roles and responsibilities of each participant in the program, described the basic actions required of and to be taken by each of the signatories (LEAA Project Manager, City/Police Department Representatives and Aerospace General Manager), and established a mechanism for additional, more detailed, agreements which would be required as the program advanced. These details would have included the data system interfaces, software changes, personnel assignments, use of police department facilities, modifications to city/police department-owned vehicles required to install the improvements, and the like.

Three subcontract procurement packages were prepared for the Field Test Program. Subcontractors to be selected, via a competitive bidding process, were:

- vehicle integration subcontractor,
- base station subcontractor, and
- field test conductor subcontractor.

The vehicle integration subcontractor was to be responsible for vehicle design, procurement and installation of all necessary equipment into the 20 police cars, their test and checkout, and field service support throughout the field test phase. Training of police patrol officers in use of the equipment was also included.

The base station subcontractor was to be responsible for the design, procurement, installation, test, and checkout of all base station equipment; the interface with the base station computer; the writing of all software required for the base station computer interface and the digital radio link interface; and support to the program throughout the field test phase.

The Field Test Conductor subcontractor was to be responsible for the conduct of the field test throughout all phases. Tasks included preparing questionnaires and other survey material, collecting all data resulting from operations, maintaining continuous surveillance of the field operations, alerting the program management and the equipment subcontractors to program problems requiring immediate attention, participating in training police personnel, along with the equipment subcontractors and the preparation of final evaluative reports.

Aerospace, as prime contractor and systems engineer, had overall responsibility for directing and guiding the subcontractor effort.

I. <u>Selection of subsystems for field test</u>

Early in the planning and design of the improved police car, it was recognized that more valid concepts had been advanced and were feasible than could be funded for an ideal test and evaluation. The overall funding constraint on the program forced restrictions in some areas such as the number of patrol cars. This chosen number, 10 cars per city, was felt to represent an absolute minimum to acquire statistically valid data, considering potential vehicle down-time.

Accordingly, decisions on priorities had to be made which resulted in the various components or systems to be categorized as "baseline" or "alternate." The baseline configuration components were carefully selected to represent a minimum program which was worthy of field test and evaluation. The selection was further refined during prototype testing, which included both baseline and alternate concepts. The selection process was also influenced by discussions held with the Advisory Council of Police Chiefs, and with personnel of the participating departments in Dallas and New Orleans.

The alternate configuration comprised a second group of subsystems which increased the concepts to be tested, plus expansion of the number of cars equipped with baseline components. These independent or increased number of subsystems were considered separately as addenda to the baseline proposals and would have been added, as funds were made available.

Table 3-1 lists the system components of the improved police patrol car, showing numbers of each planned to be installed. Baseline and alternate configurations are shown.

A brief discussion of each item follows:

- The emergency warning system (standard) was to consist of light bars, sirens, and public address systems, currently used by the New Orleans and Dallas Police Departments.
- The emergency warning system (improved) alternate offered advanced capabilities designed to enhance safety of operations. It provided a more flexible directional control of lights, special spot and strobe lights, and two acoustically tuned sirens with an unlimited "musical score" via tape recorder inputs.
- For the improved front seats, console and printer, the seats were of the Man Factors design developed for the prototype program and incorporated an improved restraint system. The console was a centralized control for the warning system, hands-free communication, and other lighting. The printer provided a hard copy of all messages and reports generated by the patrol officer when desired.
- The fuel economy components were devices to provide driver aids for monitoring fuel consumption. They included a vacuum gauge of engine performance, a miles per gallon meter displayed via the data system, and a fuel totalizer for input to the data system.

Table 3-1. Total Number of Cars Equipped

	Baseline Configuration		Alternate Configuration	
	Dallas	New Orleans	Dallas	New Orleans
Emergency Warning System-Standard	10	10	0	0
Emergency Warning System-Improved	0	0	10	10
Improved Front Seats, Console, Printer	5	5	10	10
Fuel Economy Components	10	10	10	10
Antilock Brakes	5	5	10	10
Power System	10	10	10	10
Status Sensors	10	10	10	10
Mass Memory with Cassette	5	5	10	10
Hands-Free Communication	10	10	10	10
Digital Radio Transceiver, Voice Radios	10	10	10	10
Data Processor	10	10	10	10
Keyboard, Main Display, Heads-Up Display	10	10	10	10
Carbon Monoxide Monitor	0	0	10	10
Wide Angle Rearview Mirror	0	0	10	10
Multiple Spark Discharge	0	0	10	10
Hand-Held Digital Terminal	0	0	10	10
Automatic Vehicle Location	0	0	10	10

- The antilock brakes were to control all four wheels in accordance with the designs developed and tested for the prototype vehicle.
- The power system provided the power required for operating all systems in emergency, normal, and standby operations with the engine off. A second battery was provided for data system operation in the standby mode.
- The status sensors provided both analog and discrete measurements for up to 83 vehicle condition sensors. The exact nature of this mix was to be specified in the interface control document, with inputs from the field test conductor.
- The mass memory with cassette provided a large block of random-access memory (16 k bytes) which was loaded by means of tape cassette. A wide variety of information could be stored, dependent on the operating procedures of the police department.

- The hands-free communication provided for voice transmission and reception without moving hands from the steering wheel. Two systems were to be evaluated -- the Ear Comm and the boom microphone system.
- The digital radio transceiver provided digital communications between the vehicles and the base station via the terminal keyboards. Voice radios were the standard transceivers used by each police department and provided backup for the digital communications system.
- The data processor provided primary control of all data systems and peripherals using a microprocessor with separate functions stored in programmable, read-only memories.
- The keyboard, main display, and heads-up display had separate functions. The keyboard provided a standard set of alphanumeric and punctuation characters required for the standard message formats and control signals. It included special function keys for status reporting, such as EMERGENCY/OFFICER NEEDS HELP. The main display has a capacity of 256 characters (8 lines of 32 characters each). In addition to being readable from both front passengers and driver seats, it was to be readable under conditions of bright light and darkness. The heads-up display provided an alerting display for the driver, visible with the driver's peripheral vision but not interfering with his normal field of view. It provided one line of 32 characters and alerted the driver to incoming messages, to the need for acknowledgement, and to out-of-tolerance conditions detected by the vehicle status sensors.

- The CO monitor provided a useful method of evaluating the extent of CO pollution in the patrol vehicle passenger compartment. The measurements were to be presented to the data system in parts per million for display and/or analysis.
- The wide-angle rearview mirror turned out to be a very controversial device during demonstrations of the prototype vehicle, evoking strong responses, both positive and negative. It was considered doubtful that a satisfactory design to meet all specifications could be achieved without expensive roof modifications. As specified, it provided a rear field of view, unobstructed, of 60 degrees horizontal and about 10 degrees vertical.
- The multiple spark discharge device provided for a multiple spark over 20 degrees of engine rotation to increase the probability of ignition and thus fuel economy. Fouling of spark plugs during idling was minimized.
- The hand-held digital terminal provided for complete audio and digital communications with both the vehicle and base station for the officer out of car. While greatly extending the utility of the data and communications system, it was a complex system and one of the most expensive alternates.
- The audio system provided for a flexible control of alternate audio sources and links, such as tape recorder and rear seat monitor. It was also required if the hand-held terminal alternate was selected.
- The automatic vehicle location (AVL) system could be of great value for reducing response time and for aiding in fleet operations. However, its full utility could not be realized without a computer-aided system.

B. Field Testing

General

At the beginning of the program, a decision was made that the monitoring and evaluation of the field tests would be performed by an independent contractor, who would be selected through a competitive procurement process. Considerations influencing this decision were:

- The evaluation should be conducted in an objective and unbiased manner.
- The contractor selected must not have been associated with the police car hardware or software development or production.
- Aerospace, as the systems engineer, should not be directly involved in the evaluation of its own system design.

The desired qualifications of the field test contractor included:

- Appreciation of and familiarity with methods and techniques to evaluate the performance of police patrol and dispatch operations;
- Knowledge of fleet operations including maintenance;
- Expertise in the behavioral sciences and the measurement and evaluation of personnel performance and man/machine interfaces;
- Good knowledge of the various statistical analyses applicable to the data which would be acquired and of the data processing techniques required; and
- Experience with police communications and dispatching and in particular computer-aided dispatch and mobile digital communications.

The selected contractor possessing these qualifications was to be tasked to provide answers as to the degree of success found in achieving the following goals:

- Extension and improvement of officer productivity and capabilities. Was the patrol officer aided to operate more safely and effectively in the detection, identification, and apprehension of suspects; in responding to requests for assistance; and in providing a full and accurate record of his activities for subsequent legal or statistical use.
- Improvement in safety and economy. Was safer vehicle operation provided through improved rearward visibility, better braking under adverse road and traffic conditions, more attention-getting visual and aural warning signal devices?
- Reduction in vehicle down-time, lowering maintenance costs. Were vehicle problems anticipated through continuous monitoring of important functions and alerting of the driver and the dispatcher so that corrective action was possible prior to failure? Was scheduled maintenance based on instrumentation data?
- Determination of hardware operability, acceptance by, and value to the police officer. At the conclusion of the program, there was to have been an assessment of officer acceptance and use of the various improvements relative to existing equipment and procedures. The assessment was to have included a review of equipment functioning, reliability, limitations, ease of installation, operation, and maintenance. Some of the particular items which were to be evaluated are listed in Table 3-5.

2. Data sources

Data sources to be used in the field test evaluation were to have included:

- existing police records as normally prepared and maintained;
- automatic logging of all digital data transactions between the patrol cars and base stations;
- questionnaires given to all direct participants and other involved personnel;
- survey type interviews of participants;
- observation of police operations, in patrol cars, at the dispatcher's location, and at maintenance sites;
- a test conductor master log, recording significant problems, level of participation, etc. maintained continually throughout the field tests;
- hardware malfunctioning and maintenance reports;
- software reports, covering data system operations and program fixes or revisions.

3. Data analysis and evaluation. The test planning required development of a general analysis philosophy and of methods which would be used to process the test data and to communicate the evaluation results and conclusions. Certain basic and inherent difficulties were recognized. On the one hand, the assessment of results would be based on data taken in specific scenarios for a finite, relatively limited amount of time. Conversely, the reported results would be studied by large diverse

segments of the law enforcement community who would be attempting to fit the findings and conclusions to their special locales and needs. It was therefore decided that the field evaluation program would serve primarily to indicate concept feasibility and to provide some scientific basis and guidance to those making decisions regarding the applications of the technology and implementations of the system(s) analyzed. The analysis philosophy was translated into four stages or phases of evaluation tests. These are illustrated in Figure 3-2 and pertain to general evaluation test planning, analyses in support of test planning for the specific scenarios, test data analyses performed during testing, and determinate analyses and evaluation.

The planning work performed prior to cessation of effort on the program related entirely to the first of these four stages.

4. <u>Field test training program</u>. An essential and basic part of the field test plan for evaluation of the patrol car was a comprehensive and continuing training program, implemented prior to the introduction of the improved patrol cars into actual police operations and lasting throughout the entire testing period. This training was intended to be adaptive to changing needs and problems as they arose during the field tests.

The program was to have encompassed all police and associated city personnel who were to be directly involved in the program, plus other personnel whose duties required that they have an overview of the program in order to provide support or administrative direction if and when required. The depth and extent of training provided would have varied proportionately to the involvement and knowledge requirements of the various individuals. The goals of the training program were to:

GENERAL TEST PLANNING ANALYSIS

(Stage 1)

- GENERAL GOAL/ OBJECTIVE DEFINITIONS
- GOAL, OBJECTIVE RELATIONSHIPS
- GENERAL RESEARCH DESIGN, PROCEDURE CONSIDERATIONS
- TYPICAL EXAMPLES IN SUPPORT OF RESEARCH DESIGN AND TO DEMONSTRATE ANTICIPATED ANALYSIS
- PROTOTYPE ASSESSMENT

▶

SPECIFIC SCENARIO PLANNING ANALYSIS

(Stage 2)

- STATE QUESTIONS AS QUANTIFIED HYPOTHESES
- REFINE RESEARCH DESIGN FOR SPECIFIC SCENARIOS COMPARABILITY
- SPECIFY DATA SOURCES AND STATISTICAL METHODS FOR EACH OBJECTIVE
- SPECIFY TRAINING
- SPECIFY DATA REQUIREMENTS (that is, PRECISION, SAMPLE SIZE FOR TEST/CONTROL, AND PROBABILITY LEVELS)
- ACQUIRE PRETEST DATA BASE
- ANALYZE DATA AND SELECT SITE

▶

TEST INTERIM ANALYSIS/ REFINEMENT

(Stage 3)

- ASSESS EARLY DATA vs EXPECTED DATA COMPARISONS
- REDEFINITIONS/ MODIFICATIONS OF TEST HYPOTHESES
- REFINE ANALYSIS/ EVALUATION TOOLS
- DATA TESTS VIA BOTH PARAMETRIC AND NONPARAMETRIC CONSIDERATIONS
- ASSESS HARDWARE PERFORMANCE
- MONITOR CONDUCT

▶

DETERMINATE TEST ANALYSIS/ EVALUATION

(Stage 4)

- FINALIZE DATA ANALYSIS/ EVALUATION TOOLS
- PERFORM ANALYSIS/ EVALUATION ACCOMPANIED BY TRACEABLE RATIONALE
- STATE TEST SITE AND EXTRAPOLATED RESULTS
- REPORT RESULTS/ CONCLUSIONS/ RECOMMENDATIONS
- ASSESS COST/BENEFIT
- FORMALLY DEACTIVATE TESTS

Figure 3-7. Evaluation Test Phases

- provide sufficient orientation and basic knowledge to maximize effective use of all equipment being tested;
- ensure uniformity in operating procedures and reporting so the validity of collected data and analysis were preserved;
- enable rapid and frequent communication to participate throughout the course of the program so that modification of change test procedures could be implemented when needed;
- receive prompt feedback from police officers for assessment of their satisfaction/dissatisfaction/reactions to particular aspects of the test.

The training program was to have taken into account the rotation of officers (in New Orleans) and changes in assignment to the test cars. This condition occurs in the normal course of operations due to required court appearances, vacation leave, illness or injury, and the like. A sufficient group of officers were to be trained to ensure that the field test vehicles were continuously manned with officers trained in their operation.

5. Training responsibilities. The training program was to have required joint participation by the three associate subcontractors (i.e., for vehicle integration, base station, and field test) acting in concert under the direction provided by the prime contractor. The equipment manufacturers were to have had prime responsibility in providing training directly related to the operation of their equipment. The field test conductor was to have been responsible for assuring uniformity of training procedures and orientation, maintaining a continuous on-the-scene presence to closely monitor

equipment usage, and supplying updated training information and material as required. The field test conductor was to immediately alert Aerospace and, as indicated, the equipment subcontractors as any problem arose requiring their attention.

IV. VEHICLE CONFIGURATION IMPROVEMENT STUDIES

As planned and discussed during the initial Chiefs of Police Advisory Council in January 1975, several vehicle configuration improvement design studies were performed in parallel with development of the vehicle and data systems improvements. The results of these studies are contained in the individual Aerospace reports on "Alternate Police Patrol Car Body Design Studies" (ATR-76(7914-01)-3), "Automatic Vehicle Location Systems for Law Enforcement Applications" (ATR-76(7914-01)-1), and "Assessment of Drive-Train Systems for Dual-Mode Performance in Police Patrol Vehicles" (ATR-76(7914-05)-1), prepared for the Law Enforcement Assistance Administration.

A. Design of Improved Body Configurations

1. Planning and procurement

The alternate police patrol car body design study was conducted as a part of the Police Patrol Car Systems Improvement Program. This relatively modest effort was carried out during the latter part of 1975 and the first part of 1976. Products of this work were three independently performed preliminary design studies. A summary of these studies, together with recommendations for follow-on work, were delivered to the Law Enforcement Assistance Administration in June 1976.

The purpose of these studies was to provide preliminary design concepts for police patrol car bodies that would provide significant weight reduction for fuel economy, while functionally enhancing human and equipment interfaces.

Ground rules for the study were that the new or improved body design must be installed on an existing chassis using existing engines, drive trains, and running gear, available in 1977 through 1980. The developed concepts were to reflect what could realistically be provided by the automotive industry at relatively low volume production and be competitively priced with currently available police patrol cars.

The proposed body configurations produced by the study ranged from making sheet metal modifications on the upper body of a standard four-door sedan to construction of a totally new body with low-cost tooling which could be installed on an existing utility vehicle chassis such as the Chevrolet Blazer or Dodge Ramcharger.

It was concluded that certain of the proposed designs were feasible and merited further investigation.

The desirable features of an improved police patrol car were established through reference to a previously conducted survey sponsored by the Law Enforcement Assistance Administration in 1972 and also by direct visits and interviews with representative and knowledgeable law enforcement agencies around the country. From this activity, major inadequacies and deficiencies in present police vehicle design were identified as the following:

- Inadequate head room and leg room--front and rear,
- Marginal access to rear seat (often used for transporation of handcuffed detainees),
- Uncomfortable seating restraint system that impedes rapid ingress/egress and movements to operate controls,
- Poor equipment storage and accessibility (in particular, the shotgun),

- Seat barrier (required to constrain detainees from attacking officers in front seat) further constricts marginal rear seat space,
- Crash protection,
- Equipment intrusion into front seat space, and
- Poor visibility, especially to rear.

The contractor solutions to these deficiencies ranged from making minor modifications to an existing body design to construction of a completely new body.

B. Vehicle Location System Studies

As one of the tasks associated with the improved police patrol car, The Aerospace Corporation conducted an in-house survey and technical assessment of automatic vehicle location systems for law enforcement applications ("Survey and Technical Assessment - Automatic Vehicle Location Systems for Law Enforcement Applications," ATR-76(7914-01), with the objective of acquainting the potential user with the practical, technological, and administrative factors that should be considered in the definition of performance requirements, the selection of a system, and its integration into the overall police patrol operation.

In support of this objective, four major tasks were undertaken.

- A survey of representative police departments within the United States to determine potential applications of the technology, how a system would be integrated into police operations, and the priority placed on system application.

- A review of the technical and operational problems experienced by system manufacturers and users in implementing an operational automatic vehicle location system.
- Modeling and analysis of police dispatch operations and search strategies to establish relations between operational requirements, police patrol characteristics, and automatic vehicle location performance parameters.
- An independent technical analysis of the performance capabilities of six commercially available systems, an assessment of the advantages and disadvantages of the three categories of the technology, and the derivation of representative life-cycle costs.

The results of each of these tasks were employed in a systems engineering design study to establish the relationship between needs and performance parameters and to identify the factors to be considered in selecting a cost effective system for a specific application.

The findings of the survey and assessment indicated that system performance parameters are definable as a function of intended application, patrol characteristics, and for certain applications, the geometry and topography of the operational area. The category of technology most suited for a specific police operation will be determined by such factors as its intended use, its integration with current and planned patrol systems, and in some cases, by the willingness of local authorities to cooperate in its implementation. As a consequence, performance parameters and system configurations will be unique to individual police operations, and the selection of the most cost-effective system must include a thorough assessment of all technical and nontechnical factors.

C. Assessment of Drive-Train Systems for Dual-Mode Performance

As another of the tasks associated with the Police Patrol Car Systems Improvement Program, The Aerospace Corporation performed an in-house analysis and evaluation study effort related to methods and techniques whereby the fuel consumption of police vehicles could be reduced. The study report, "Assessment of Drive-Train Systems for Dual-Mode Performance in Police Patrol Vehicles" (ATR-76(7914-05)-1, May 1976), was delivered to the Law Enforcement Assistance Administration at the conclusion of this work.

The specific objective of this study was to evaluate the suitability and effectiveness of various drive-train devices or modifications which could reduce fuel consumption in police patrol vehicles by enabling them to be operated selectively in two performance modes: an economy mode suitable for nonemergency patrol activities and a power mode for chase and other emergency patrol operations.

This objective was to be met by means of (1) the characteristics of police patrol vehicle use modes and performance characteristics to establish the requirements and specifications for dual-mode system operation; (2) the identification and characterization of drive-train devices or concepts potentially suitable for dual-mode police patrol vehicle use; (3) and initial comparative evaluation of contending concepts to identify the most promising concepts in terms of police vehicle compatibility, potential for fuel economy improvement, emissions effects, and state of development;

(4) the analysis of each promising device with regard to resulting fuel economy gains; and (5) a final evaluation of relative merit considering device availability, vehicle modifications required for adaptation, and cost versus value of fuel saved.

The initial assessment and screening considered eight candidate systems in terms of fuel-economy potential, police-vehicle compatibility, and state of development. This work established that four of the concepts examined deserved additional consideration and analysis, while four others did not show sufficient potential to be carried further in the study effort. The successful candidates selected for further examination were:

- Supercharging,
- Bilevel drive ratio device,
- Modular-engine system, and
- Variable-cylinder engine.

General conclusions and findings relative to the use of these devices were:

- Supercharging (also termed turbocharging) equipment is fully developed and available for use on today's police cars; fuel economy improvements would range from approximately 10 to 25 percent, depending on driving-cycle assumptions and the specific techniques applied.
- The bilevel-drive ratio is commercially available and would provide a fuel economy improvement of 15 percent in the highway driving cycle, but less than 3 percent in an urban duty cycle; thus, this device only has utility for highway patrol applications.

- The modular-engine system has theoretical improvements of nearly 34 percent in the urban driving cycle, highest of all systems analyzed; however, this system is in a very early stage of development and the time when it will be commercially available cannot be predicted (highway cycle improvements are estimated at 25 percent).
- The variable-cylinder engine was analyzed in two versions--carbureto controlled and value controlled. Both are in an advanced development state. The first commercial version of a valve controlled engine is scheduled for introduction in 1977/78 (Ford Motor Co., six-cylinder engine). The fuel economy gains for a carbuerto-controlled engine are estimated at approximately 13 percent and for a valve controlled engine, at 17 to 19 percent. These figures apply to an urban duty cycle. The highway duty cycle improvements are much less--2 to 6 percent.

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