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Equipment Systems Improvement Program – Development

Feasibility Demonstration of a Truck Anti-Hijacking System

Prepared by
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Engineering Science Operations

July 1973

DEVELOPMENT

Prepared for
LAW ENFORCEMENT ASSISTANCE ADMINISTRATION
U.S. DEPARTMENT OF JUSTICE

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Law Enforcement Development Group
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ABSTRACT

A truck anti-hijack system was designed, assembled, and demonstrated, that satisfies the case of an urban delivery truck operating over any prescribed route. The system employs a simple calibrated odometer supported by capabilities for hijack detection, engine disabling, and aural and visual beacons. The design uses no direct driver interaction and operates autonomously in the case of a hijack event. The base, or dispatcher, station equipment requirements are simple and economical. System performance and costs are discussed and considered reasonable. Recommendations for additional effort are offered.

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ACKNOWLEDGMENT

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SUMMARY

A developmental prototype truck anti-hijack system was conceived, designed, fabricated, and tested by personnel of The Aerospace Corporation in response to a feasibility demonstration task defined by LEAA. The primary purpose of the effort undertaken was to demonstrate the feasibility of providing a viable anti-hijacked truck system. The locator method was chosen to solve the specific case of a truck fleet delivering goods in an urban area over a known travel route. The constraint of a priori knowledge of the travel route permitted the use of a simple odometer that had been calibrated to decrease the systematic error to below 0.5%. The odometer approach, as implemented in this feasibility demonstration, defines the point of hijacking to about 1000 ft, and then, as a system, provides the data and signals to permit a law enforcement agency to locate the truck with confidence in a reasonable time frame. The system has a potential of providing locations to approximately 100 ft. The support functions were designed to minimize driver interaction and provided hijack detection, engine disabling, and audible and visible alarm signals. Operation of the system is relatively simple and blends with the normal administrative operations that typify delivery truck operations. The major impact on a truck operation would be the use of a communication link between the truck fleet and a base station. For those truck fleets that utilize two-way communication, the additional impact of the locator system is relatively slight. The cost of the system is estimated to be about twice the cost of the communication system alone.

CHAPTER I. INTRODUCTION

This report describes the development and test of a hijacked truck locator system that was generated in response to a request by the LEAA. The task was initiated in December 1972 and was completed in June 1973. The particular design requirements were developed from a generalized scenario of truck hijacking that can be described as follows:

> A truck, which is a member of a fleet of trucks not exceeding 1000, is used for delivering goods in an urban community. The truck route is specified prior to initial dispatching, and involves "n" stops (where $n > 2$), all of which are located within a single metropolis. Assume that a hijacking occurs somewhere during the delivery run. The task is to provide a demonstrable system that permits location of the truck at hijack time within a time constraint of 5 min (with a goal of 1 min) and an accuracy constraint of 1500 ft (with a goal of 500 ft).

It was apparent from this scenario that it was not necessary to develop a system to locate a vehicle in a two-dimensional space. The prescribed route constraint permits the problem to be reducible to a one-dimensional problem if the freedom of moving the truck after hijacking is prohibited. This latter characteristic can be achieved by disabling the vehicle after hijacking. This, in itself, is a desirable action to aid in defeating and apprehending the hijackers. It should be made clear that this system does not satisfy the requirement of location for an arbitrary, unplanned route, and should not be construed to have been designed for that type of operation. Since the location problem becomes a one-dimensional problem, a one-dimensional transducer, an odometer, is used to determine the elapsed distance. The location data as measured by the odometer is telemetered to the base, or dispatcher, station on a voice channel of a UHF radio communication link. The hijack event must be detected to initiate transmission of the odometer data and to disable the vehicle. It was decided to detect the hijack event and operate the odometer and disabling units without any direct interaction with the driver. Thus, the driver of the truck could not modify the system operation without working through the base station to get the support of dispatcher actions.

This system utilizes a radio link for telemetering of data and for remote command management from a base station. The total system can autonomously detect a hijacking, telemeter the odometer data with a label that identifies the truck, disable the truck, and provide loud audible and bright visible alarm signals. The base station can address one unique truck out of a thousand with commands to operate the system, simply interrogate the status of the system, provide written records of each communication to the base station from the truck with a local time statement, and provide a truck location by street identification, using the preplanned route, the odometer reading, and a simple map of the city. In addition, the system operation lends itself to a simple but adequate administrative control over a fleet of trucks from a relatively low cost dispatching station.

The system was tested in a truck van in the Los Angeles area, using a communication system that was primarily used by internal company security personnel for their day-to-day operations. However, the system was generally operated so that the radio communication link was adequate, and no attempt was made to design a communication system that would operate with high confidence in the entire Los Angeles urban complex.

It is planned that, as part of the FY 74 program, demonstrations of the operating system will be given to knowledgeable personnel in trucking, law enforcement, and insurance organizations for comments concerning the system operation. The testing to date has been limited to a short term accuracy evaluation of the odometer sensor, and the operating characteristics of the supporting subsystems.

CHAPTER II. SCOPE

This section will identify the design requirements, design ground rules, and objectives of the system. The general requirements were defined in a task description that was negotiated with LEAA. The specific ground rules and objectives were developed and established without the benefit of documentation, but were mutually developed between The Aerospace Corporation and LEAA personnel.

A. Design Requirements

The truck anti-hijacking system was to satisfy the following requirements:

- Provide location of a hijacked truck to within 1500 ft, with a goal of 500 ft.
- Provide the location data in a timely fashion to permit knowledge of the location in 5 min, with a 1-min goal.
- Provide service for a fleet of trucks (not to exceed 1000) that operates in an urban environment along delivery routes that are known and are a constraint on the driver.
- Provide a high level of immunity from system malfunction due to accidental interference from external sources or typical truck environment.
- Design toward minimization of the equipment volume and cost.
- Design toward minimal in-line system interaction by the truck driver. All system operations should either be autonomous, or

require that either the dispatcher (in the base station) or the driver and dispatcher jointly perform actions to operate the system.

- Provide a written record, as well as visual displays, of the system operation.

B. Ground Rules

As the system concept developed, some ground rules for the design evolved that were used to guide the system configuration. These ground rules were incorporated largely because of the short time available to develop, fabricate, and test the system. They are listed below unconditionally, although, in general, there was agreement with LEAA that they be observed.

- Wherever possible, use commercially available equipment to provide the system functions.
- Use existing corporate capital equipment to support the system development and operation wherever possible.
- Minimize design efforts to the system for high immunity to a physical attack by knowledgeable hijackers, since the main goal was a feasibility demonstration.
- Do not attempt to optimize the mechanical packaging of either commercial or Aerospace-fabricated packages.
- Consider low power dissipation as a desirable design feature.
- Provide a communication system that is adequate for feasibility demonstration.

- Take every simple design option available to improve system reliability (such as derating of components) but do not employ redundancy or high reliability components to enhance reliability.
- Do not include self-diagnostic or special test capability into the design.
- Restrict design of the hijack detection sensor subsystem to the use of simple switches to indicate door open/close status.

It is noted here that the ground rules used for this design do not represent the design requirements that should be applied to any future system, but rather were expediencies to permit assembly of the system in the required time frame.

C. Objectives

The primary objective of the task was to produce a demonstrable hijacked truck locator within the scope of the requirements and ground rules defined previously. In the process of producing the system, the secondary objectives were to establish the feasibility of satisfying the requirements, and to provide a baseline system which could be made available to LEAA for future use.

CHAPTER III. SYSTEM DESIGN CONFIGURATION

The equipment designated to be in the system is the odometer and the equipment providing the supporting functions. This demonstration system is complete in the sense that it does provide to the user reasonably accurate location data within the scope of the defined requirements. In the sections that follow, the development of the system concept is discussed, with some statements regarding the merits and limitations of the system; the subsystem detailed descriptions are also provided.

A. System Concept and General Description

Proceeding from the design requirements and ground rules defined in Paragraphs II-A and II-B, we considered two major primary designs. The first involved elapsed time from the last known point, and the other considered elapsed distance from the last known point. Although the former system simply required notification of the hijack event, it was shown easily that the errors in location could be expected to exceed 50,000 ft per hour of elapsed time. The elapsed distance approach was then examined, and from documented data,[1] it was apparent that the location error could be contained below 200 ft per mile of elapsed distance, which appeared to satisfy the requirements. For communication of the elapsed distance information to the dispatcher, it was necessary to include a data link, which was incorporated into the radio communication link. To ensure that no unplanned motion of the truck occurred after the hijack event, we found it necessary to detect the

[1] 1971 SAE Handbook.

hijack and disable the truck; accordingly, that capability was included. Detection of the hijack event required some form of intrusion alarm, which in turn required a capability to arm and safe the intrusion alarm. Since a design goal was to minimize driver interaction, it was planned to arm and safe the system remotely from the dispatcher site, again using the radio communication link. This latter remote command capability was designed so that more commands could be given than the simple binary arm/safe. The command table has been expanded to include a driver exit command, and could easily be further expanded to provide commands for additional functions. For test purposes, a status panel, which provides visual indications of the status and the odometer reading, was incorporated into the mobile equipment.

The locator system could suffer errors on the order of 1000 ft after 10 miles of elapsed distance; therefore, it was felt that some terminal location aid would be desirable. The spotter system was incorporated to satisfy that need; it consists of high level visual and aural signaling. The visual signal is primarily included for spotting from the air, and the aural signal for spotting from other ground vehicles.

In support of the power requirements of the truck-borne portion of the system, a "stand alone" power source was provided in the form of a lead-acid storage battery.

The dispatcher station, which is communicating with many trucks (demonstration configuration can handle 999 per station), one at a time per channel, had some specific design requirements to support the overall system. The location problem required adequate maps and map-reading equipment to translate the elapsed distance measurement into a specific identifiable location in this urban complex. It was found that U.S. Government maps with a scale of 1/24, 000 are available that provide readability to 300 ft and that are accurate to about 1 part in 10, 000. The cost of these maps is trivial, and they provide the transfer function from elapsed distance to street location admirably. They are available for the entire United States area. Elapsed mileage readers designed to operate in conjunction with these maps are available commercially. These readers suffer from readability resolution of about 500 ft, but are simple, rugged, and economical.

In addition to a visual indication of the data and command status of each truck at the dispatcher station, it was considered important to generate a written record of that data. As a result, the dispatcher station includes a printer that logs each communication from every truck, with a time-of-day listing. This capability provides some deterrent to aid in preventing dispatchers from being accessories to a hijack event, and also provides a useful written history of the movement of the trucks.

In the demonstration design, it was a ground rule to not complicate the system with features that were included only to defeat the potential hijackers. Therefore, no anti-spoof or hardening, or special alarm systems were included in the present design. It is recognized that the system is vulnerable to physical attack and that the communication link is not immune from a directed attack. However, there are recognized modifications that could be made to improve the immunity to these attacks. These improvements will be defined during the FY 74 program.

The various functions discussed above can be seen as an interconnected system. Figures 3-1 and 3-2 are photographs of the major components of the truck-borne electronics and the dispatcher station, respectively.

B. Subsystem Descriptions

The overall system can be categorized fairly naturally into several subsystems. These are taken as separate units below, but the interfaces between subsystems are discussed within the pertinent areas.

Although not a subsystem, it might be useful to describe the vehicle used for the mobile portion of the equipment. The truck is leased by The Aerospace Corporation for this purpose. It is a 1969 Ford Econoline truck with a guarded rear area. No special modifications were made to the truck, except installation of the electronics in the dashboard, of the communications antenna, and of the door monitors. A photograph of the truck is provided as Fig. 3-3.

1. Odometer subsystem. The requirements here were to exploit the standard odometer drive cable with a separate pickoff to operate an electronic counter. An electronic counter was needed to provide a simple interface with the other electronic equipment used to transmit the data to the base station. A search of commercially available equipment revealed only one source of appropriate equipment (Laboratory Equipment Corporation). The commercial product, which is named TRACTEST, is commonly called the "fifth wheel." One of the purchased components was an electronic wheel actuator mechanically designed with standard SAE fittings so that it would interface with standard truck odometer cable drives. Another component

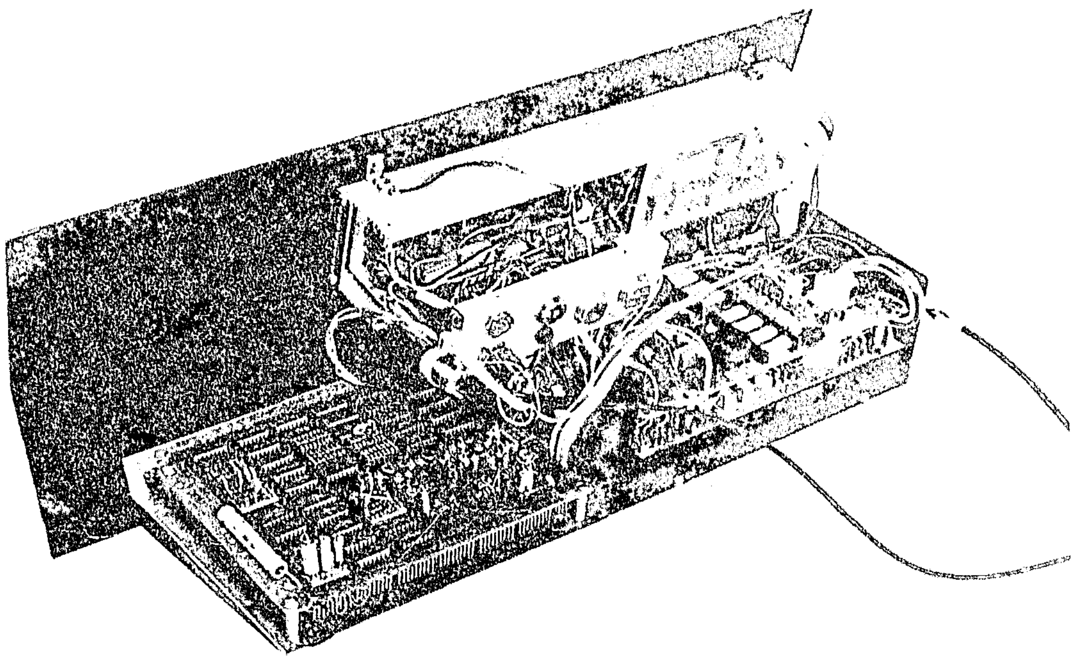


Fig. 3-1. Major Components of Truck-Borne Electronics

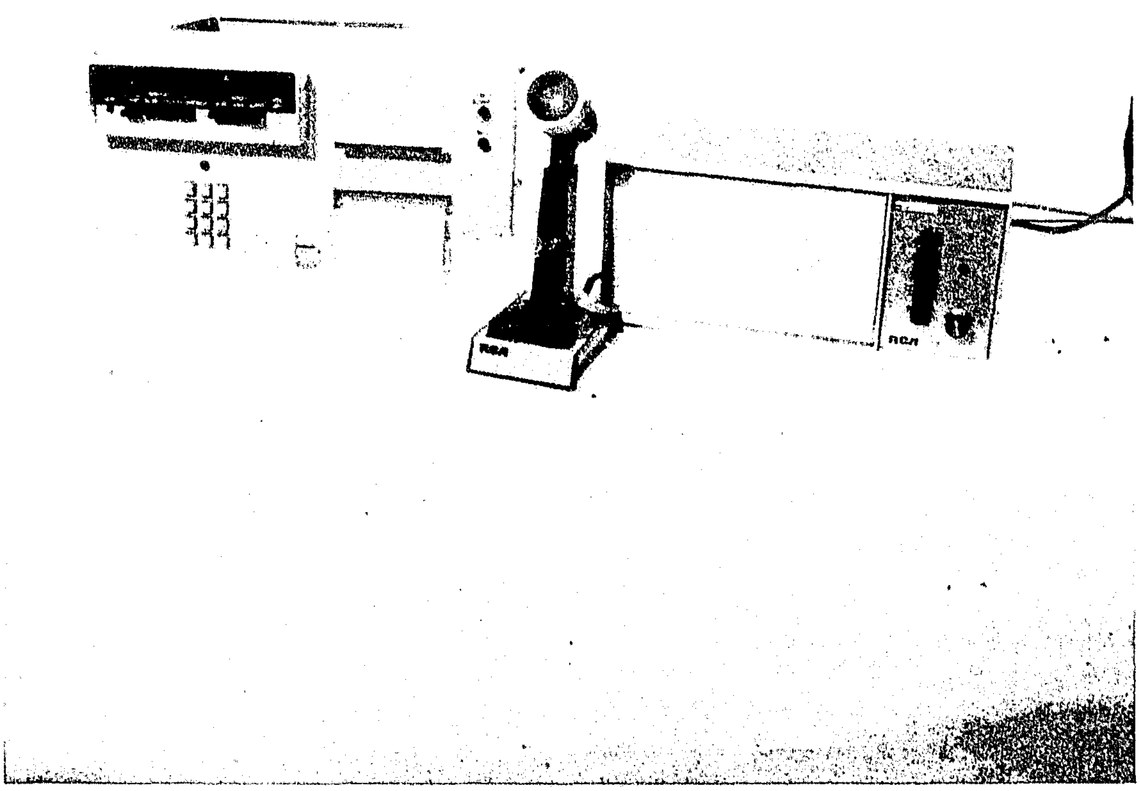


Fig. 3-2. Major Components of Dispatcher Station

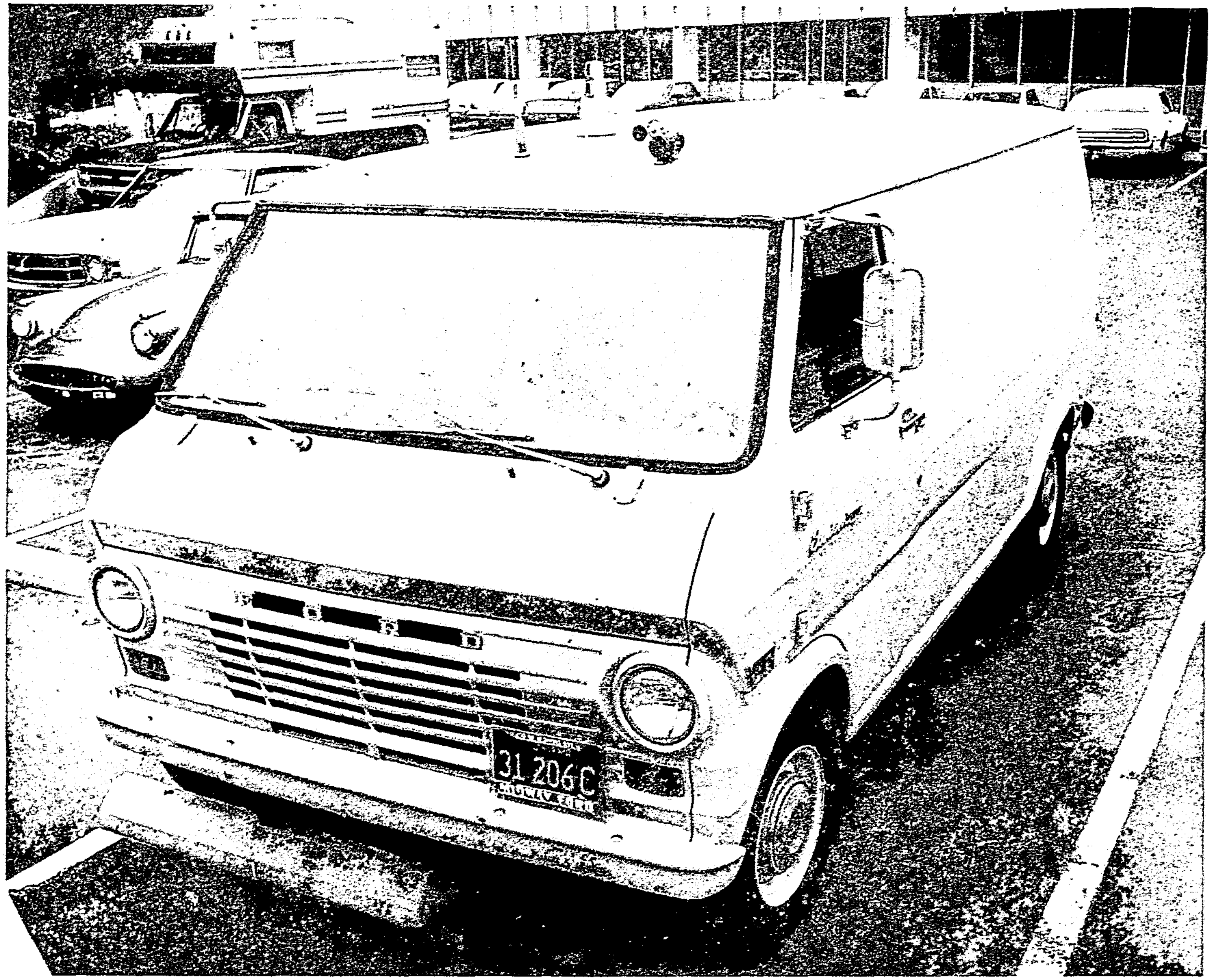


Fig. 3-3. Truck Used for Mobile Portion of Equipment

was an electronic counter designed to interface with, and count the pulses from, the wheel actuator. This counter also provided an adequate interface with the rest of the electronic system. The third TRACTEST component was the fifth wheel assembly. This was used to independently calibrate the odometer operating in the truck. The systematic error of the original truck system was measured using the TRACTEST system with the wheel actuator and counter driven by the fifth wheel.

Then appropriate gear ratios were installed in the truck drive so that, when the wheel actuator was driven by the truck cable through those gears, the indicated pulses from the actuator were calibrated to 1 pulse per foot of truck motion. Agreement with the fifth wheel results were maintained to a value less than 0.5%. The electronic counter was combined with the overall electronics so that the total mileage could be telemetered, and so that the counter could be reset to zero as required. Since the commercial counter had a built-in reset at 5280 ft, that reset pulse was used in a 0 to 99 miles counter. Only the thousands digit of the TRACTEST counter was used in the data transmission system, although all digits were displayed on the status display panel.

To support the odometer read-out in the base station, we procured a set of maps that are available from the U.S. Geological Survey to cover the Los Angeles urban complex. These maps are available at several scales. The scale chosen for the station was 1/24,000, which permits clear identification of all streets. At that scale, 1 statute mile is about 2.5 in. on the map. The distances on the map were conveniently read with a commercial device that uses a wheel to integrate the traversed distance as it is rolled along the defined route on the map. The device used here was calibrated to match the 1/24,000 map scale. Thus, with only very simple equipment in the base station, the telemetered odometer data can be converted to city street locations in a matter of minutes. If a computer were used to preplan the truck route, a simple odometer versus street location checklist could be generated for each route.

2. Telemetry, command, and control subsystem. By the ground rule of utilizing existing corporate equipment, the basic voice link was chosen to be The Aerospace Corporation Security operations. In fact, it was desirable to use a link with other voice traffic, since any problems of interference or compatibility could be identified. In addition, it would have been difficult to license an experimental system in the UHF band in a short time period. The channel in use is at approximately 165 MHz, and the channel is licensed for voice communication. The characteristics are very similar to communications utilized by commercial trucking concerns. To conserve funds, we used vacuum tube rather than solid-state equipment for the radio frequency link. The penalty in weight and power dissipation is quite high, and any future effort should use a solid-state mobile transceiver. The mobile transmitter was rated at about 12-W output and is pictured in Fig. 3-4. The base station transceiver was located on the roof of The Aerospace Corporation A-1 building. It was operated remotely from the basement of the same building, where the base station was located.

Fig. 3-4. Mobile Transceiver

Use of the link for digital data transmission had to be performed in a manner that complied with FCC regulations. At present, it is not proper to utilize pulse modulation for digital transmissions on a voice channel. Research into accepted commercial practice disclosed that tone modulation technique for digital transmission was in use. Since commercial equipment was available to implement this technique, it was decided to use tone modulation. A search through commercial equipment revealed some equipment that provided the desired base station functions and some of the mobile functions. The manufacturer is Speedcall Inc., located in Hayward, California. No other manufacturer produced equipment as close to the system requirements. Review of the Speedcall commercial equipment characteristics revealed the following:

a. The equipment was designed primarily for the management of large vehicle fleets where the vehicle driver relays the status of the vehicle to a central base station through a manual control (a set of numbered switches, with each number representing a predefined status).

b. The mobile encoder/decoder is not designed to receive a multiplicity of commands from the base station. It is preprogrammed to expect a certain sequence of tones within a certain time period. If this requirement is not met, the system will reset.

c. The options offered, such as automatic ID echo response and automatic alarm cycle, seemed attractive to meet the design requirements.

d. The mobile and base stations are designed to transmit and display an 8-digit frame, which was easily adapted to the particular data requirement of our application.

e. The basic circuitry, after detailed review, permitted relatively easy interface and minimized the modification for the feasibility demonstration.

f. The system had a reputable field history and was an indicator that it would be a reliable base upon which to implement the more advanced system.

On the basis of these facts, the Speedcall Inc. equipment for the mobile and base stations was purchased and incorporated into the system design.

The major support subsystem is a simple form of telemetry, command, and control with bidirectional data transmission as shown in Fig. 3-5. The base station is composed of the existing Aerospace RCA transceiver, which has been interfaced with the Speedcall Inc. data control station. The data control station has a keyboard input and an 8-digit display, which allow the base station operator to send and receive data. In addition, the data control station has a printer and clock, which allow a given data reception to be logged onto the printer with the time. The mobile station consists of an existing Aerospace mobile RCA transceiver, which has been interfaced with a Speedcall Inc. mobile data encoder/decoder. Interfaced to the encoder/decoder is a specially designed logic module, which allows the mobile station to automatically monitor vehicle status and, when properly interrogated from the base station, to transmit the vehicle status. This logic module, hence

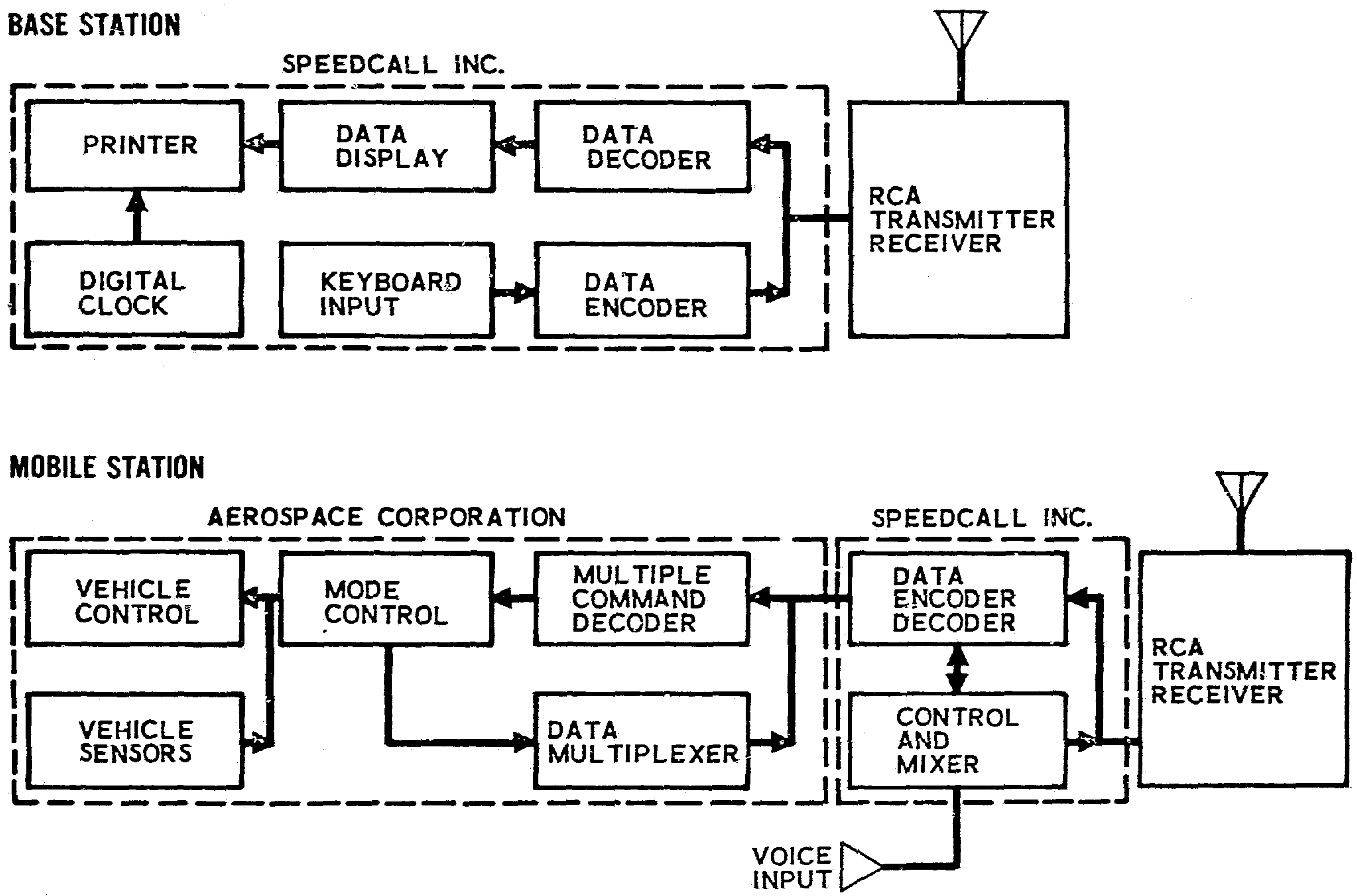


Fig. 3-5. Major Support Subsystem

referred to as the control and monitor unit (CMU), also has the task of decoding the multiple commands and cycling the data from the truck sensors into the proper sequence for the Speedcall encoder/decoder. The CMU will disable the vehicle when one of its modes has been compromised, and can be commanded to enable the vehicle from the base station. It is important to note that the vehicle cannot be disabled from the base station, only enabled. The decision to disable the vehicle can only occur autonomously at the mobile unit. Enabling cannot be done at the mobile station, only at the base station.

The mobile system operates within a set of predetermined conditional states. The first state is the SAFE mode. In the SAFE mode, any of the vehicle doors can be freely opened. When the SAFE mode is initiated, the odometer is set to zero. The vehicle can be moved either forward or backward a total increment of 400 ft before a state change will occur. The choice of 400 ft was arbitrary, and can be modified. Thus, the SAFE mode allows the cargo to be loaded or unloaded with some flexibility of moving the vehicle within given limits. If the 400-ft limit is exceeded, the ALERT mode will be initiated, which causes that vehicle status to be transmitted automatically to the base station, and starts the ALARM timer.

If the system has not been commanded out of the ALERT mode within 70 sec (arbitrary choice), then the ALARM timer runs out, and the CMU will advance to the ALARM mode, which disables the vehicle by opening the automotive ignition primary circuit and by disrupting normal carburetor operation.

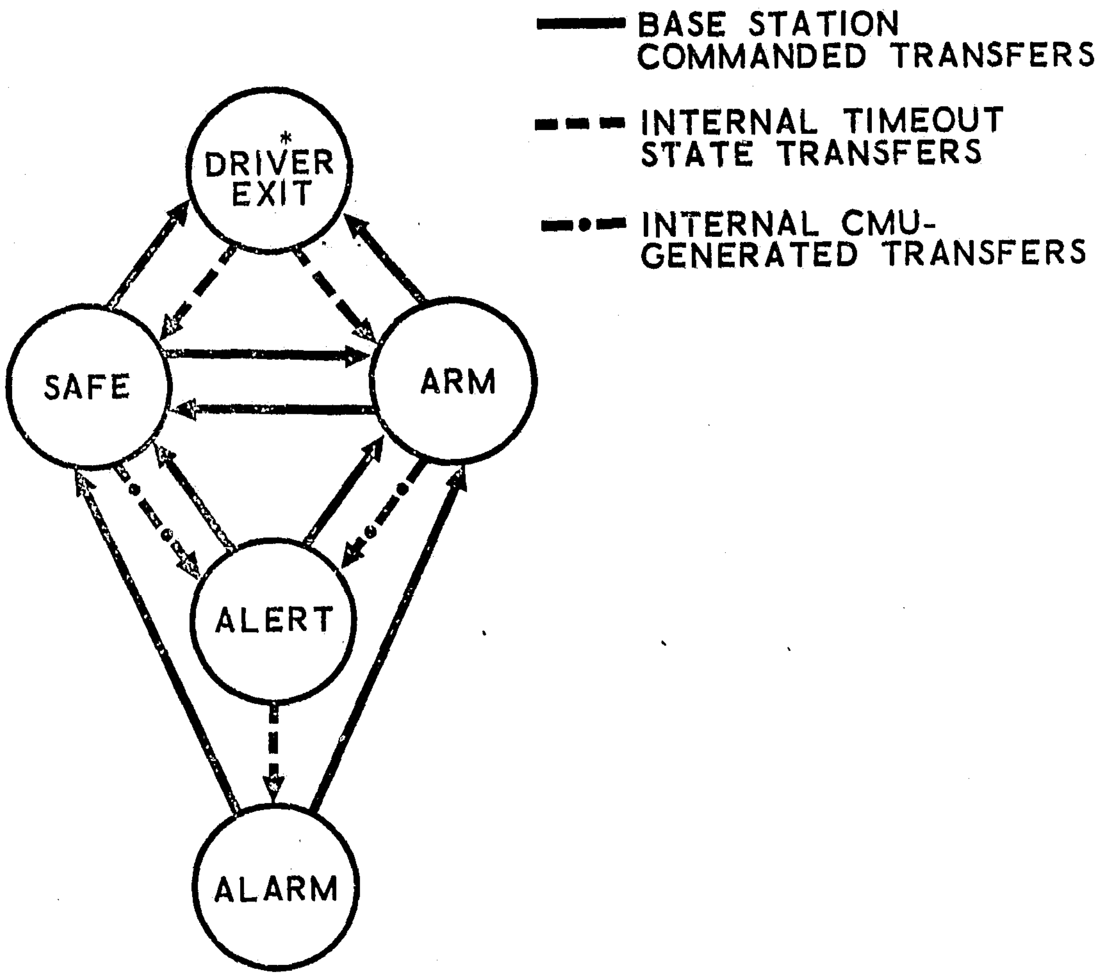
In ALARM, the CMU also turns on a high powered horn and light, and causes the vehicle status to be transmitted automatically every 10-15 sec.

The mobile unit will stay in this mode until either the auxiliary power supply is drained or the CMU is commanded into the SAFE or ARM mode by the base station.

The other operational mode is the ARM mode. This mode allows the vehicle to be moved any distance without a change of CMU state; however, if any of the vehicle doors is opened, the ALERT mode is entered and the system progresses into the ALARM sequence. Results identical to those described before will occur, provided a reset is not sent from the base station within the allotted 70-sec period.

Another base station controlled state is the DRIVER EXIT mode. This mode allows the CMU primary state to be unchanged while the door monitors are disabled for a 30-sec period. This mode facilitates certain expected short stops during the driver's route and allows the vehicle to be left unmanned in the ARM state at the end of the delivery or vehicle shutdown time. These few operational modes allow the system to be very flexible and totally functional. Refer to Fig. 3-6 for the system state diagram.

The CMU has been designed so that the power is divided into two categories because certain portions of the mobile system consume too much power to be left on all the time. These portions are turned off at the end of the working day, when the vehicle is located at its storage area. The CMU (low current portion) is left on and still provides protection to the vehicle when left in the ARM mode. In this prototype system, the odometer circuit is a high current drain circuit and has to be turned off. This means the system should be placed in the ARM mode when the vehicle is left at the end of the



*The DRIVER EXIT is a pseudo-state. The CMU maintains the previous state (SAFE or ARM) while being in the DRIVER EXIT state.

Fig. 3-6. Mobile System State Diagram

working day. Refer to Fig. 3-7 for the portions of the CMU that are high current.

The mobile system is supplied power from an auxiliary power supply. This auxiliary power system is a 12-V automotive battery that has special terminals for the system power and returns, and has an isolation diode. The auxiliary power supply is charged from the automotive alternator, and yet is isolated from the regular automotive battery. The system receives its power from the alternator when the vehicle is running, and from the auxiliary battery when the engine is turned off. Refer to Fig. 3-8 for the auxiliary power system block diagram and to Fig. 3-9 for a photograph of the auxiliary power unit.

The communications link used for this prototype is simplex, operating at approximately 165 MHz. The data and voice frequency modulate the carrier in a standard manner as approved by FCC rules. The data is converted from the digital form to a dual-tone form as used in the touch-tone dialing system. In this system, each number is represented by a dual-frequency tone. These tones are divided into low frequency (698- to 941-Hz) and high frequency (1209- to 1477-Hz) sets of pairs that identify each digit. The tones are sent from the base station to the mobile unit at the relatively slow rate of 2 to 3 tone pairs per second. The mobile decoders are adjusted to accept these tones at this slow rate and reject tones at a faster rate. When a mobile unit replies, it is at a faster rate of 12 tones per second. These rate differences have been used to prevent one mobile unit from responding to a transmission from a second mobile unit. This is of concern only when the mobile

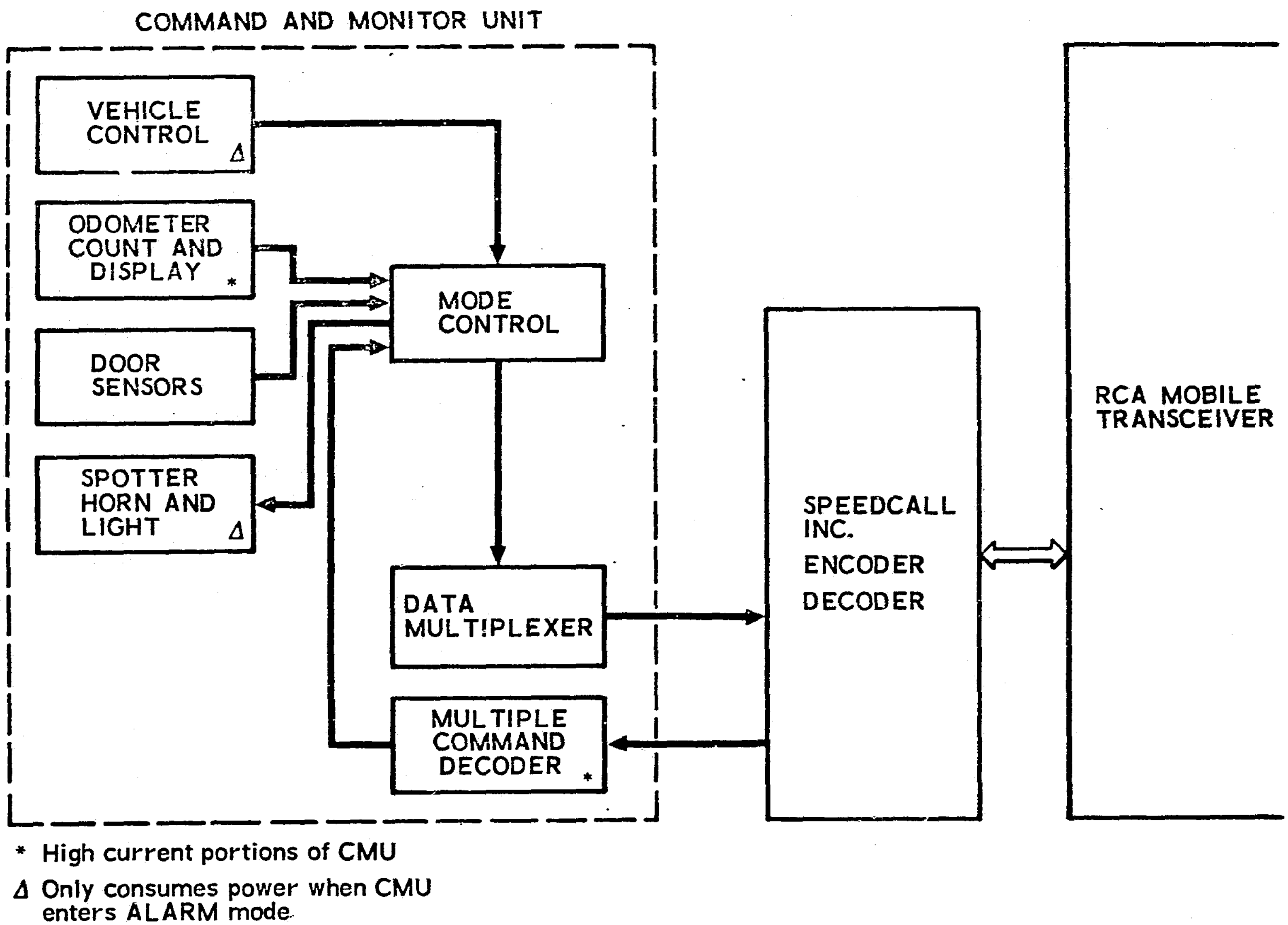


Fig. 3-7. CMU Block Diagram

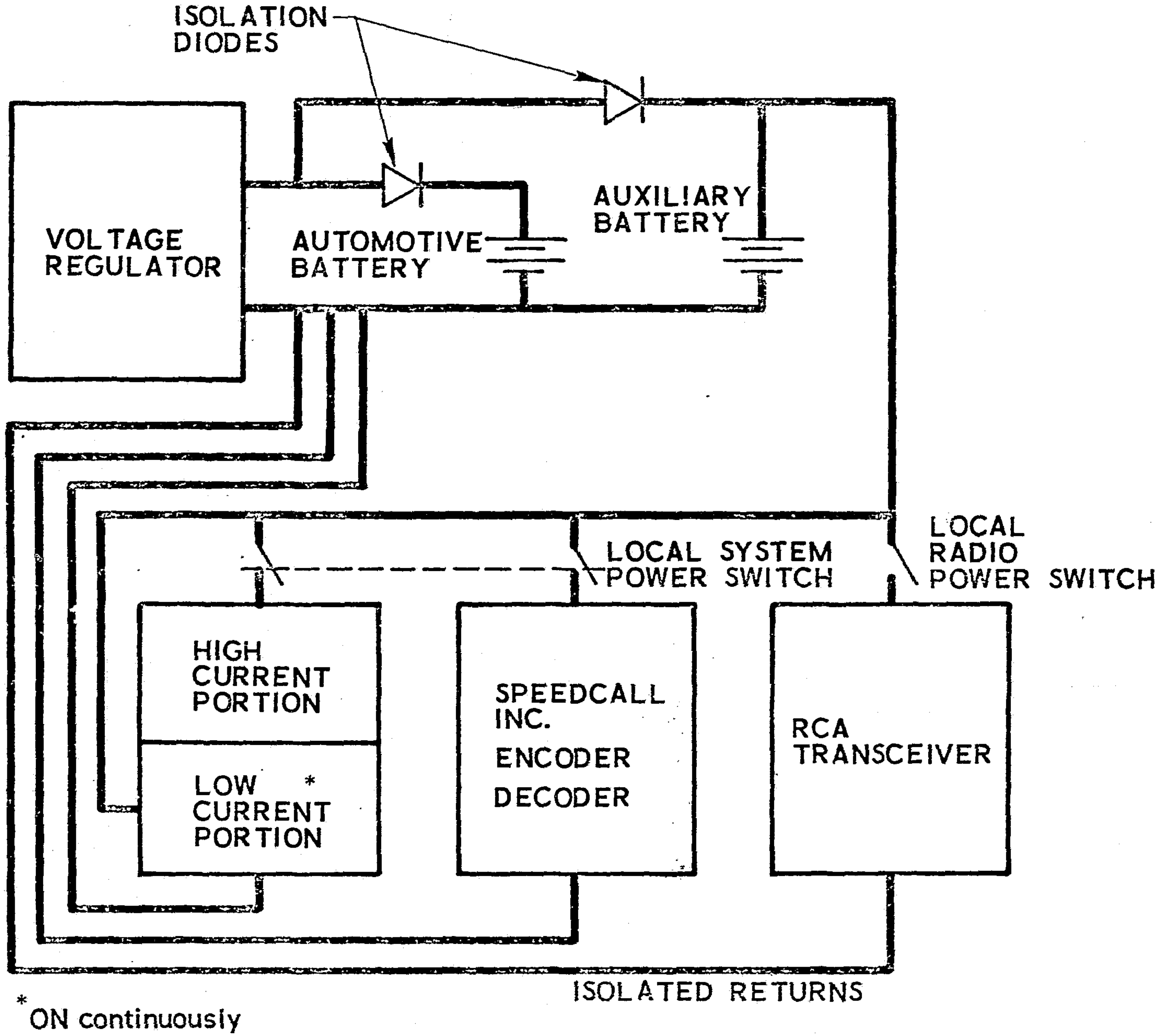


Fig. 3-8. Auxiliary Power System Block Diagram

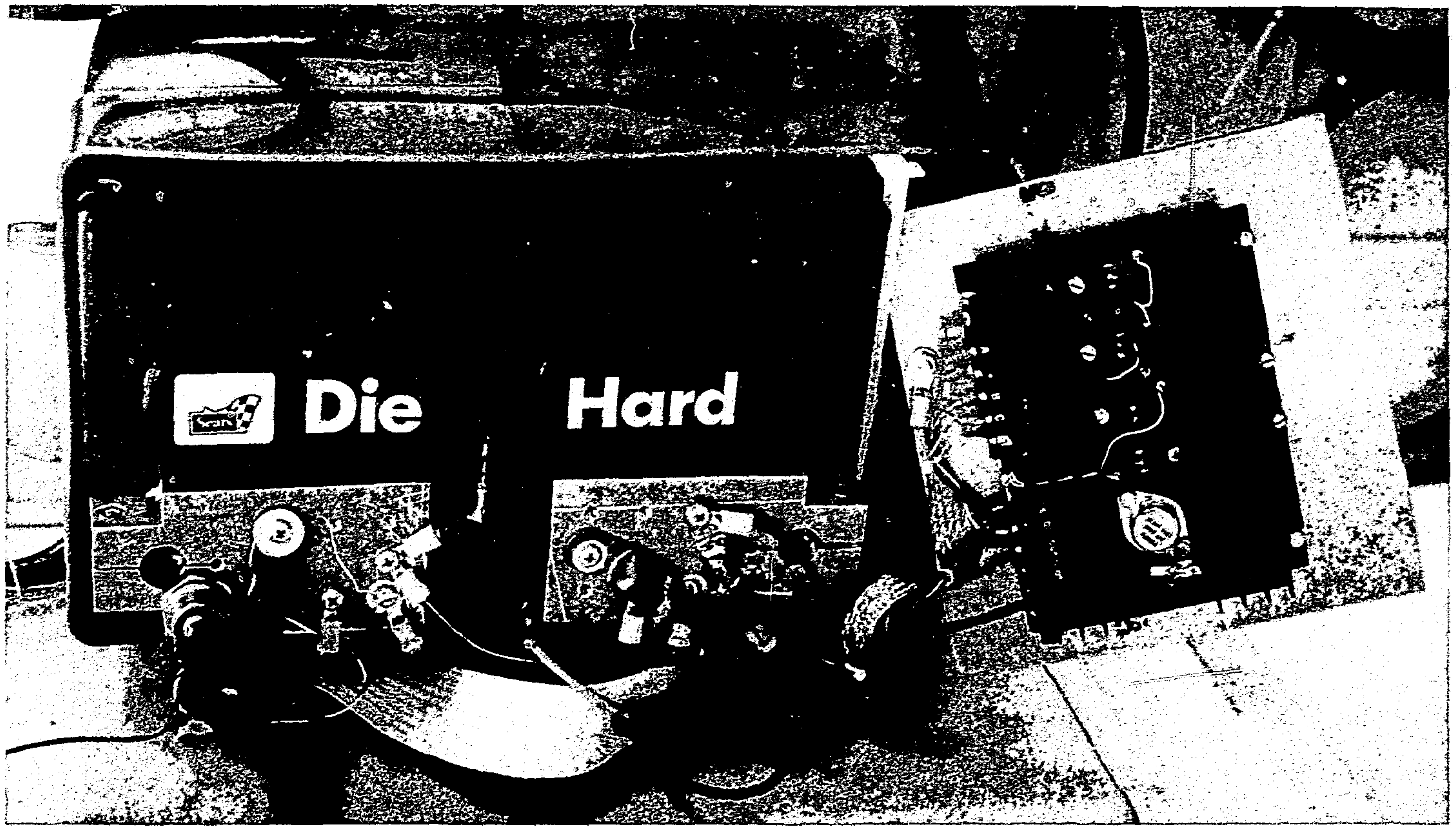


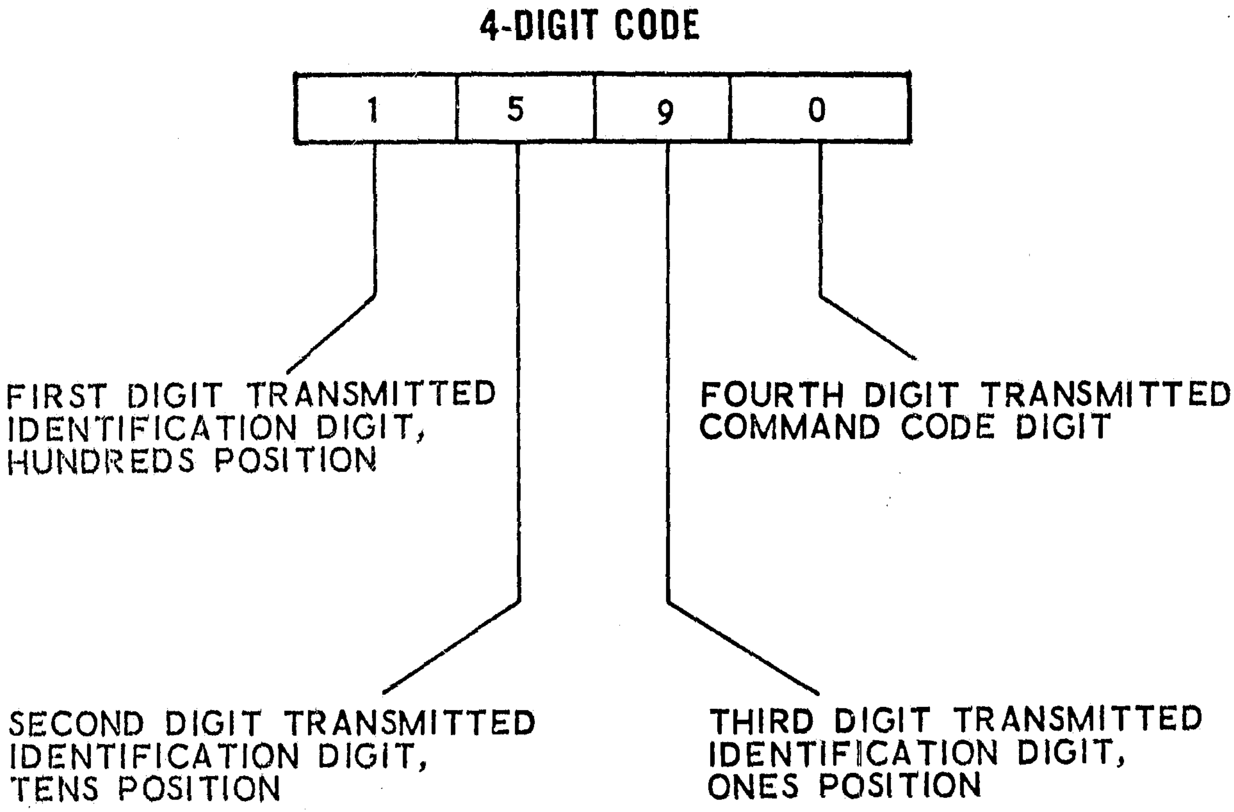
Fig. 3-9. Auxiliary Power Unit

unit has a long data frame and the base station has a short command frame, as in this case.

The base station code consists of a 4-decimal-digit transmission, of which the first 3 digits are the vehicle identification code. The fourth digit is the command code digit. This is presently 0 for SAFE, 1 for ARM, or 2 for DRIVER EXIT. Refer to Fig. 3-10 for the format map. The CMU is reset by sending one of these commands if its existing state was ALERT or ALARM.

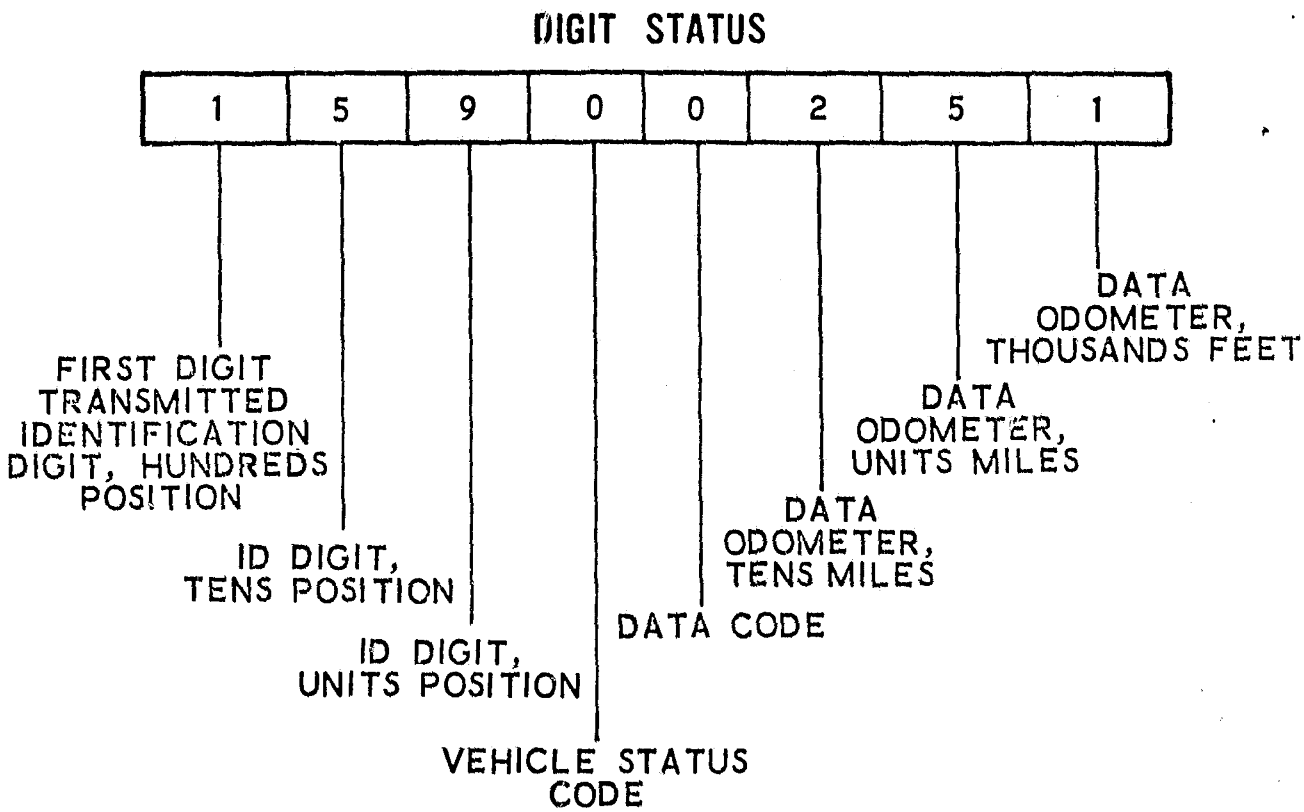
The mobile station transmitted code has an 8-digit frame length. The first 3 digits are the vehicle identification code. The fourth digit is the status code. The fifth digit is the data identification code; this digit tells the base station operator what information the next three digits represent. In the prototype, this digit is always 0, and the following three digits are always the vehicle odometer reading. Refer to Fig. 3-11 for the detailed format map description. The design is capable of growth to a more varied telemetry output.

A status display panel forms the face plate of the mobile electronics chassis. The panel uses light emitting diode (LED) displays to show the status mode of the CMU and to provide the digital reading of the odometer. In addition, manual switch functions are available to control the high power portions of the system and to manually intercede for disabling the horn, light, and engine disable units. These latter switches are for test purposes only, to avoid inadvertent operation of those units during the evaluation program; these switches could be electronic switches under remote control, if



DIGIT	COMMAND
0	SAFE
1	ARM
2	DRIVER EXIT
3	SPARE
4 - 9, *, #	SPARE

Fig. 3-10. Base Station Transmitted Code Format



VEHICLE STATUS CODE

DIGIT	STATUS
0	SAFE mode
1	ARM mode
2	ALERT mode
3	ALARM mode
4	SAFE mode and DRIVER EXIT
5	ARM mode and DRIVER EXIT
6	ALERT mode and DRIVER EXIT
7	ALARM mode and DRIVER EXIT
8	Unused
9	Unused

Fig. 3-11. Mobile Station Transmitted Code Format

Because of the high power dissipation, the horn is operated in a duty cycle mode with 5 sec of "on" time and 10 sec of "off" during the ALARM mode.

The light used on the truck is an aircraft anticollision strobe beacon manufactured by Whelan Engineering Company to satisfy the requirements of the FAA. The effective candlepower is 165 in the red zone, and 750 in the white. It is operated in a continuous mode when the ALARM status occurs. It can also be seen in Fig. 3-3, page 13.

The spotter units as configured would be at variance with the California Motor Vehicle Code. However, since armored trucks have officially been given approval to operate alarm systems in case of compromise, it should not be difficult to modify existing legislation to permit the use of a spotter on a protected truck. An alternate option exists in which the horn and flashing light could be replaced by some form of silent alarm. An example is the use of police vehicle homing on the truck vehicle transmitter signal.

5. Vehicle disable unit. The vehicle disable unit was designed after consideration of a set of candidate disabling methods. All methods that operated on the portions of the truck other than the engine were discarded for safety reasons.

Two methods were installed in the demonstration system. The first, which consists of a relay to open the primary ignition circuit, is very simple to implement, but also relatively easy to circumvent. The second method was more difficult to install, but provides a disabler that is difficult and time-consuming to defeat. The principle of operation is to mechanically override the normal mode of the float valve in the carburetor. When the valve is forced open, the carburetor overflows, and the engine is effectively flooded. The plunger used to override the valve is spring-loaded and held by a detent that is released by a solenoid activated by the electrical signal given at initiation of the ALARM mode. Thus, removal of the electrical signal to the solenoid does not return the plunger to its normal position. It must be returned to the detent position manually.

Since the design of the access cover to the plunger prevents rapid removal (many screws hold the cover in place), the system can be effectively disabled for the time required to extricate the plunger. For the present design, this time is estimated at 20 to 30 min. As a result of this design, which heavily penalizes inadvertent ALARMs, a test switch on the status panel was installed to disable the circuit during the test program. A sketch of the carburetor overflow configuration is provided as Fig. 3-13. Although not employed in this design, removal of the access panel could be further delayed by random use of right- and left-handed threads on the screws. Forcible entry into the plunger would generally destroy the normal carburetor function. Diesel truck engines could use an analogous approach to disrupt the fuel supply.

C. Odometer Performance

After installation of the TRACTEST wheel actuator in the truck driven by the transmission drive cable, several runs of the truck were made over two calibration courses about 6 mi long. The mean systematic differences between the readings and those measured previously with the fifth wheel assembly were 114 ft on wet roads and -2 ft on a dry road. There were 12 runs at each condition. These represented mean errors of about 0.38% on wet roads and -0.01% on dry roads. Repeatability of the runs on wet roads showed a maximum difference of 20 ft from the mean. On the dry roads, the maximum excursion from the mean was 36 ft during 6 runs.

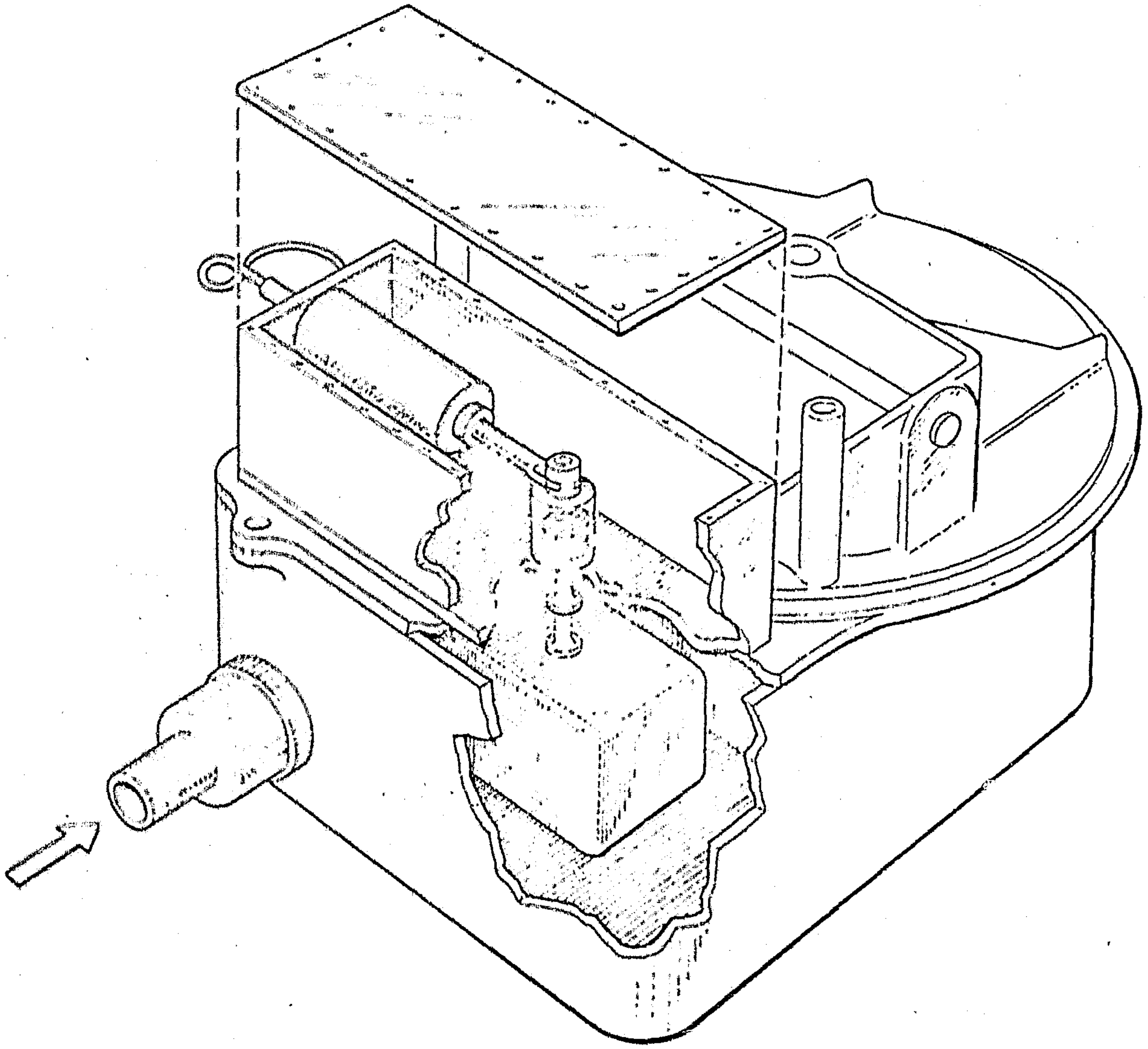


Fig. 3-13. Carburetor Overflow

Following the calibration runs, which were used primarily to verify the gear ratios installed in the drive unit, a series of runs over a simulated truck route was made. During these runs, the fidelity of the telemetry transmissions was verified. The simulated route was chosen to include travel on both surface and freeway roads, heavy stop-and-go traffic, and travel at varied speeds. The total distance per run was approximately 18 mi. Results from a series of those runs yielded a standard deviation from the mean of 65 ft. The mean difference between the odometer readings and measurements from the map used in the base station was 995 ft. These values represent less than 0.07% random error (one sigma) and 1.0% mean difference, respectively.

The testing was not complete, or detailed, enough to exactly expose how the systematic error was generated. It is speculated that lane changes and freeway access roads not accounted for on the map were the major contributors to the positive bias of the readings. It is apparent from these results that repeatibility of the odometer readings is extremely good, but that systematic error can be a problem. No attempt was made to identify or quantify the varied sources of systematic error, since they have been adequately studied by the automotive industry and reported in the open literature.

D. System Performance

After initial debugging of the system, about 80 hr of operating experience were accumulated. During these hours of operation, the performance was qualitatively evaluated and component failures were recorded and, in most cases, analyzed. Several of the integrated circuits in the odometer counter unit failed. The failed components were inspected, and the failures were attributed to simple quality problems in the components. Two failures of integrated circuits in the CMU occurred. These also were identified to be quality problems rather than design faults. A photograph taken with a scanning electron microscope of one of those components is shown as Fig. 3-14. The presence of contamination is self-evident. No component failures of this type occurred during the last 40 hr of operation.

During an especially hot day (about 100° F), an intermittent failure of the mobile equipment occurred. This was traced to a capacitor that was changing value critically in the Speedcall equipment. The failure was duplicated on the test bench with a heat source. A change to a component with more stable characteristics corrected the problem. The minimum signal-to-noise ratio at which the base station would operate was approximately 6 dB. On occasion, under severe attenuation conditions, this ratio was not maintained by the radio link, and the system would not operate consistently. This problem is not severe, and was only noted when the truck was in a tunnel, or was surrounded by large buildings. In general, if the voice link operated, the digital data could be used. Tests were performed successfully at ranges as great or greater than 20 miles.

During the entire operating period, in conjunction with the prime users of the channel, no false triggers or responses were experienced from the mobile equipment. On occasion, the transmissions either to or from the truck were preempted by other user voice transmissions, but this did not appear to be an operational problem. In most cases, a traffic period of 10 to 15 sec was adequate to complete a message.

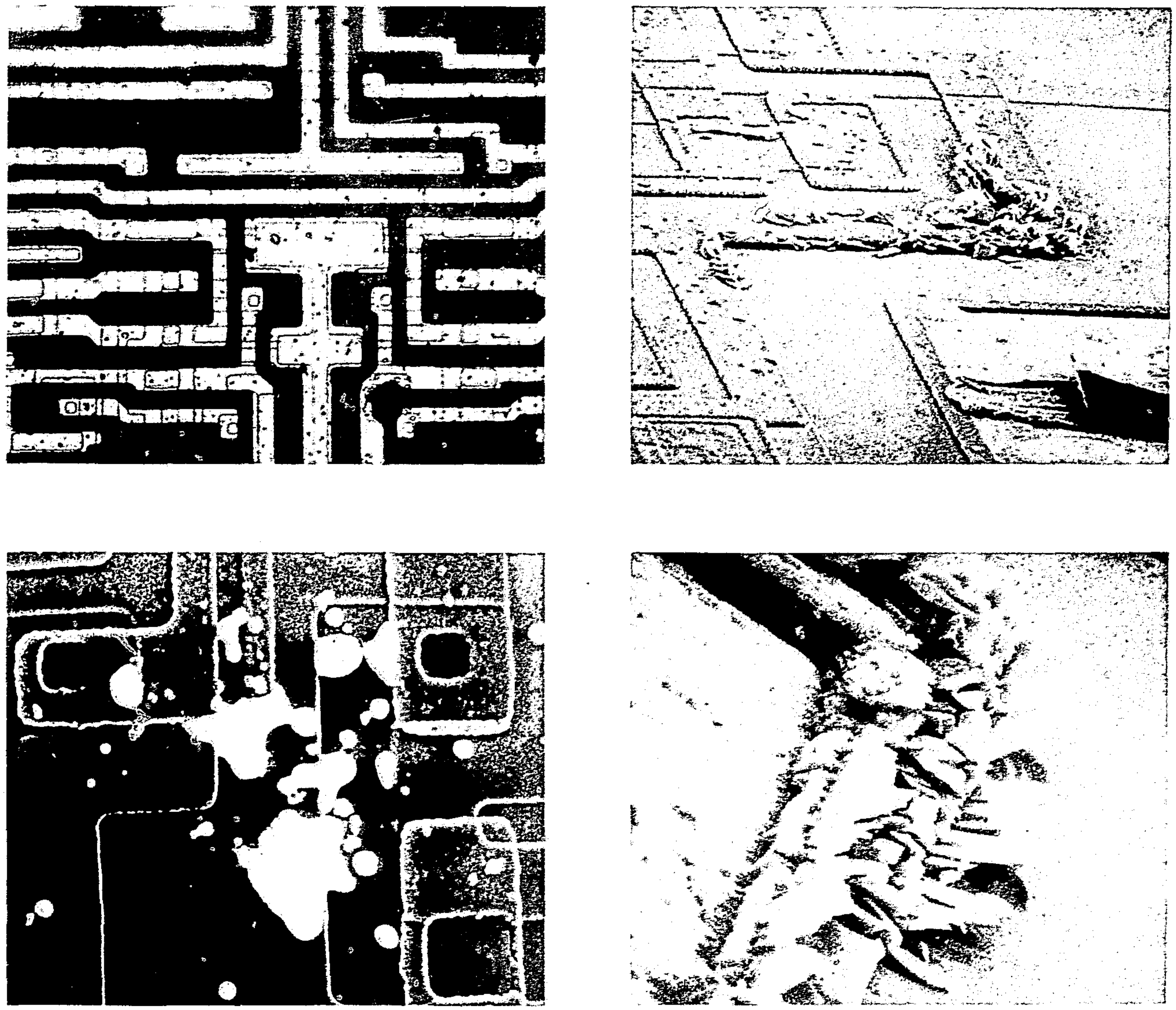


Fig. 3-14. Failed MC 14520 CL Integrated Circuit Used in CMU

During the entire operating period, there were no malfunctions noted due to electromagnetic interference (EMI). Consideration to these effects had been given in the design of the CMU, and apparently the design was immune to outside interference.

E. System Costs

An experienced cost estimator was tasked to independently compile a cost breakdown of the mobile equipment. Three estimates were generated to cover the cases of (1) using as presently built; (2) building, rather than buying, the Speedcall and odometer electronics and assuming a production rate of 10 units per month; and (3) same as (2), except assuming a producuion rate of 100 units per month. In addition, some estimates of the required volume for packaging were made. Table 3-1 lists the estimated costs and Fig. 3-15 shows an artist's conception of the electronics packages. It is seen that the mobile equipment cost will be from $2000 to $3000 and that the required volume for the electronics is about 0.3 cu ft. The cost of the base station equipment is estimated at $5000 to include the transceiver and Speedcall equipment. Thus, the cost for a 10-truck fleet is estimated to be from $25,000 to $35,000.

Table 3-1. Cost Estimates for Truck Locating System

Item	Present Configuration	10/Mo. Redesign	100/Mo. Redesign
A. OEM			
1. Battery & power switches	$ 90.00	$ 90.00	$ 72.00
2. Speedcall unit & odometer electronics	575.00		
3. Odometer transmission	50.00	50.00	40.00
4. Receiver-transmitter	800.00	800.00	640.00
TOTAL	$1,515.00	$ 940.00	$ 752.00
B. Materials & components			
1. Active devices	$ 207.00	$ 310.00	$ 248.00
2. Passive devices	40.00	59.50	47.00
3. Hardware & material	175.00	225.00	181.00
4. Sensors & display	48.00	48.00	39.00
TOTAL	$ 470.00	$ 642.00	$ 515.00
C. Labor			
1. Assembly	$ 58.00	$ 87.00	$ 65.00
2. Test	72.00	90.00	60.00
3. Touch up & pack	3.00	3.00	3.00
TOTAL	$ 133.00	$ 180.00	$ 128.00
D. Installation	$ 150.00	$ 150.00	$ 125.00
E. TOTAL	$2,268.00	$1,912.00	$1,520.00
F. Selling price	$2,995.00	$2,523.00	$1,995.00

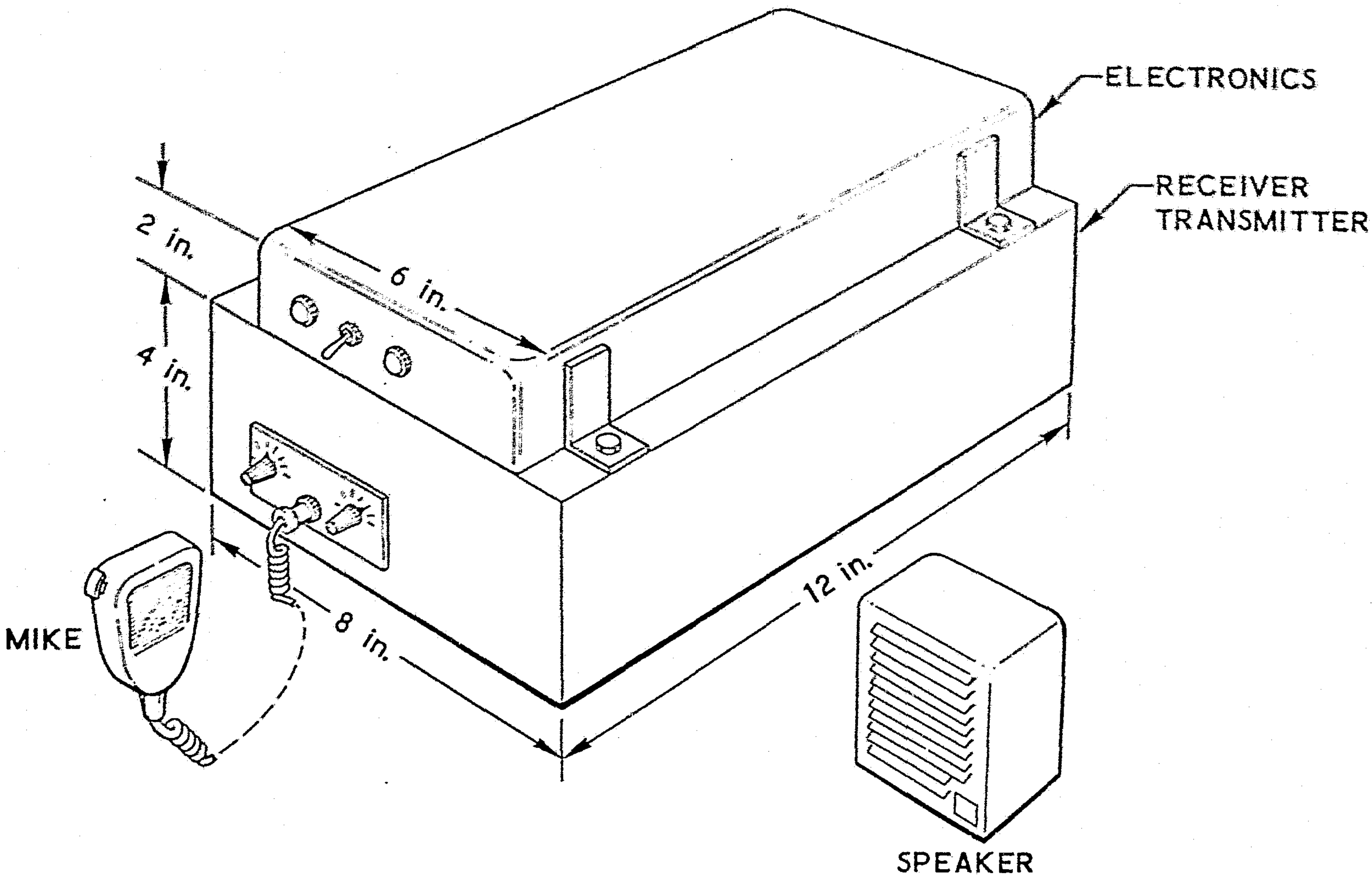


Fig. 3-15. Electronics Packages (artist's conception)

CHAPTER IV. CONCLUSIONS

- It has been demonstrated that a simple odometer can provide reasonable data to a central dispatching station, which can then simply use that data to locate a truck traveling a prescribed route.
- It has also been demonstrated that relatively simple equipment can be used to detect a hijacking and to advise the central dispatching station of the event.
- It has been demonstrated that simple modifications to a truck can, in the event of a detected hijacking, disable the motive capabilities of the truck for any desired time period.
- It has been demonstrated that a total mobile system that provides a viable method to detect a hijack, locate the truck in a timely manner, and provide administrative control, without direct intervention of the driver, can be implemented at a cost of about $3000 per truck.

CHAPTER V. FY 74 PLANS

- It is planned to demonstrate the system to cognizant parties from the trucking industry, police, and other pertinent organizations, so that their comments can be incorporated into future configuration definition efforts.
- It is planned to provide tradeoffs, or cost benefits, of achieving a higher level of immunity from physical attack by hardening of critical units.
- It is planned to investigate the cost benefits of using a duplex, rather than a simplex, communication link to prevent a single truck transmitter malfunction from tying up the entire communication system.
- It is planned to perform a failure modes and effects analysis on any future system to establish system reliability and to identify critical areas.
- It is planned to identify sensors to detect the hijack event beyond the simple door monitors in the present design.
- It is planned to continue development of the anti-hijacking system through a preliminary prototype design phase.
- It is planned to investigate devices to be used for disabling diesel engines and for securing cargo trailers to tractor equipment.

END