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APPENDICES (A, C, D, E)

"Quantitative Characterization of the Vehicle Motion Environment (VME)"

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16. Abstract
The project has addressed the "Quantitative Characterization of the Vehicle Motion Environment (VME)"—seeking to develop a key research tool for building the knowledge base on crash avoidance. By application of this tool, an archival set of data is to be acquired that documents how vehicles are actually being driven in normal usage on U.S. roads. The empirical data in this archive would characterize the trajectories and instantaneous speeds of individual vehicles in the midst of all other nearby vehicles, in everyday traffic.

The work in this project has involved the development of a measurement and processing system for generating and analyzing VME data. A complete ensemble of hardware and software subsystems has been built and subjected to initial trial.

It is clear that the initial technology selected for sensing in this phase of the work—namely, that of laser-based range imaging—is insufficiently mature at present to support the VME program. It appears that the state of the industrial art is well behind that of the raw technological art of laser range-imaging that has been demonstrated in scientific laboratories and for certain military applications. The absence of a commercial market for the peculiar type of laser sensor needed here is rather clearly responsible for the limited industrial capability in this area. The remainder of the VME hardware and software assembly is believed to be entirely utilizeable with substitute imaging technologies. Accordingly, the report examines alternative sensing technologies and establishes that digital CCD technology should be examined for application as the VME sensing medium.

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Appendix A

ITS America Paper on VME Design Approach

The attached paper appearing in this Appendix is taken from the *Proceedings* of the ITS America 1993 Annual Meeting held in Washington, D.C., April 14-17, 1993.

A MEASUREMENT AND PROCESSING SYSTEM FOR THE VEHICLE MOTION ENVIRONMENT (VME)

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ABSTRACT

With active safety technology on the horizon, there is need for an engineering tool by which to obtain a broadly representative, yet quantitative, characterization of the geometric and dynamic elements of the crash-hazard environment through which all vehicles travel. A data set providing such quantification is needed to enable studies of the response characteristics and overall performance of accident countermeasures based upon active systems in the motor vehicle. Studies of this type would support the engineering development of products, the evaluation of system concepts, and an orderly advancement of specifications and regulations for active safety technology.

Beginning in 1989, a concept for measurement and analysis of the so-called "Vehicle Motion Environment" (VME) was formed by the University of Michigan Transportation Research Institute (UMTRI) and later developed through a joint effort of UMTRI and the Environmental Research Institute of Michigan (ERIM). The initial work resulted in a report entitled, "The Feasibility of Quantitatively Characterizing the Vehicle Motion Environment."[1] In September 1992, the UMTRI/ERIM team entered into a Cooperative Agreement with the National Highway Traffic Safety Administration (NHTSA) under which a fully-functioning system for VME measurement and data processing was to be built and tested.

The system, which is now under design, employs a laser-based ranging scanner to produce an accurate quantitative data set defining the movement of actual vehicles operating in the near proximity of one another in the real traffic context. Collection of such data over a representative number of road sites would yield, over time, a VME data archive representing the near-range behavior of vehicles in traffic in the U.S. The goal of a national VME archive is clearly analogous to that of our national archive of accident data. By this analogy, we note that the accident record has provided the authoritative base of data which underpinned the scientific study, since around 1970, of crash injury and collision mechanics to support the development of "passive safety technology" (i.e., engineered features of the vehicle and roadway to minimize the extent of injury in motor vehicle crashes). Correspondingly, a VME data record will afford the foundation for scientific study of the complex motion environment in the near field of each motor vehicle, thereby supporting the development of an "active safety technology" (AST) (i.e., engineered features assisting the driver to minimize the occurrence of motor vehicle crashes) for the future.

An engineering characterization of the VME will require that real roads and traffic motions be measured at selected sites for a modest period, say a month or so, at each site. Altogether, the measurements must cover a representative sample of sites covering geographic, climatic, road design, illumination, driver, and traffic factors. At a given road site, each motion and space variable must be quantified from one instant in time to the next so that, eventually, data are collected providing statistical distributions of these variables representing the vehicle operations within which AST packages would be deployed.

The time history, or moment-to-moment quantification of the VME, would be compiled as a computerized archive and used as an engineering tool for understanding and predicting the in-field performance of AST systems. Altogether, such an archive would constitute a massive data resource and would require a sustained commitment for its acquisition and maintenance -- not unlike the commitment that has attended the compilation of the computerized accident record.

This paper will briefly articulate the rationale for VME quantification, expand upon a vision for its application, and introduce the technical approach which is being pursued toward a system design.

RATIONALE FOR VME MEASUREMENT

Without VME data, it is felt that the process of refining collision warning and intervention systems will be remarkably empirical in nature and thus quite handicapped as an engineering endeavor. The empiricism will derive from the simple fact that the pre-crash environment remains utterly unquantified. The only way one can tell if a given sensor/processor package is any good under the current state of affairs is to take it out on the road and try it. But wherever one tries it the inter-vehicular variables at the time of testing will be unknown and unrepeatable in any controlled sense, thus making it difficult to relate the package's performance to the condition variables. Given that the population of drivers exhibit a substantial level of random variation in all control actions, attempts to simulate this application environment will always lack validation until some robust form of "truth data" is brought forward through a direct-measurement characterization.

The basic problem is that we have essentially no information that is both quantitatively and statistically representative of the headways, lateral clearances, angles of approach, time spacing between vehicles, or the correspondence between these inter-vehicular variables and the steering and braking accelerations which are driver-induced in response to this "motion environment." Thus, we are without definitive data on an exceedingly complex application environment toward which a large industry around the world is now targeting a vast array of new technology, promising crash avoidance countermeasures.

The extent of the need for VME data can be seen upon consideration of the challenge in AST system development. The central observation, confirmed now by some industry engineers who have begun to work on active safety packages, is that the detection of full-blown, fast-closing collision threats is not too difficult if the system waits long enough to make a decision -- but then, the time-to-respond may be intolerably short. Many sensing technologies, even with crude processing algorithms, can tell a bona-fide crash-in-the-making when it is well-developed and more or less inevitable. The hard part is to create sensor/processor systems that can discern the "probably-harmless" inter-vehicular actions from the "very-likely-harmful" events early in the time sequence

Clearly, since candidates for crash-interaction develop around each motor vehicle hour after hour, day-in and day-out, the opportunities for false alarm are legion. The suitable active safety technology must accomplish the remarkably complex task of accepting the many thousands of episodes which are, indeed, benign while not ending up in such a mathematical stupor that the bona-fide collision threat is missed or its detection is delayed beyond the minimal time window needed for safe intervention. On the assumption that frequent false alarms and, worse yet, false control interventions, will render active safety products unusable, the achievement of high levels of "active safety intelligence" seems a requirement. But the engineering of such intelligence into these products appears, in turn, to require an accurate targeting of the technology to the complex motion environment as it really prevails. Such a task requires that the "target" be representatively quantified.

However industry may use such quantitative data for product planning and development, government may be disposed to employ the VME data for such purposes as identifying opportunities for crash avoidance countermeasures, proving AST concepts at a preliminary level, and evaluating specific system designs by subjecting them to VME sequences that have been selected from the archive for use in repeatable and statistically meaningful examinations of product performance.[2] A "standard" evaluation sequence might emerge by which industrial developers of technology can communicate with government regulators, and vice versa, perhaps eventually even using a VME data sequence to develop product standards covering certain "macro" aspects of safety performance.

A VISION FOR THE APPLICATION OF A SYSTEM FOR VME QUANTIFICATION

The core of the VME measurement package is seen as a sensor that is installed at the roadside as shown in the concept sketch in Figure 1, and which produces electro-optic images of the traffic stream and converts them into a recorded data file covering all motor vehicles passing through the field of view. In actual implementation, a group of such "sensor stations" will be deployed to provide a mosaic of adjacent measurement zones. The raw data from each sensor first arrives in the form of image data that must be processed to capture vehicles and other objects, ultimately characterizing vehicle trajectories in the form of so-called "track files," as illustrated in Figure 2. One track file is produced for each vehicle that passes through the sensor's "field of regard," -- i.e., the physical space under observation. Each track file contains a time sample of data expressing the location (in X-Y coordinates) of the geometric centroid of each vehicle as well as the vehicle's yaw orientation angle. The track file for each vehicle also contains, as a header, the length and width of the vehicle. Performance targets for the VME measurement and data analysis system have been specified in terms of track file parameters, as follows:

- time sampling rate — 10 Hz
- vehicle length and width — +/- 3 inches
- X-Y coordinates of the vehicle's centroid — +/- 6 inches
- vehicle yaw angle — +/- 2 degrees

These measurement qualities are needed over night and day time periods under any but the most intense precipitation conditions and at the site of virtually any type of roadway configuration.

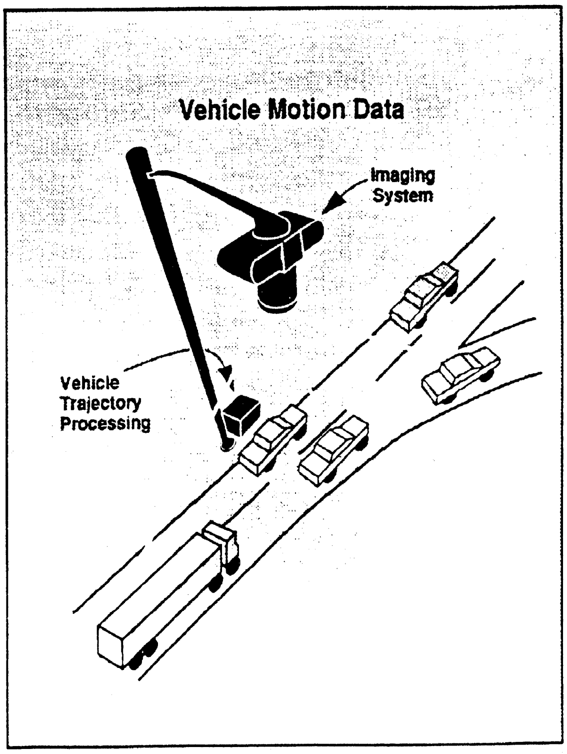

Figure 1. VME Concept

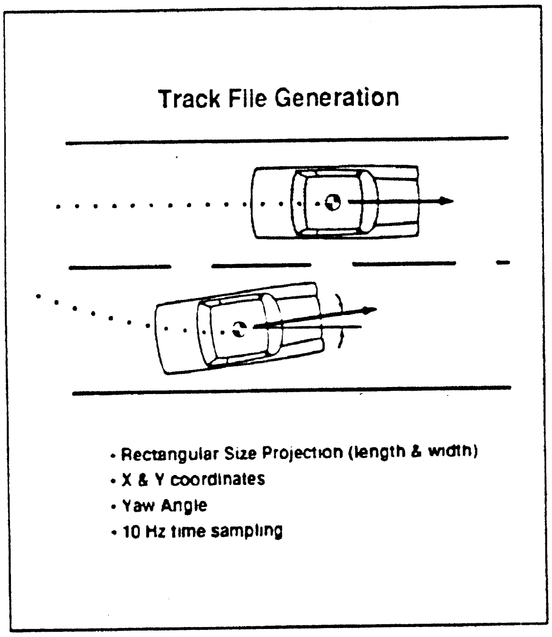

Figure 2. Track File Information

Since track files all have a common time base, later processing of these data can determine the inter-vehicular relationships which prevailed during the measurement. Such "enriched-variable files" can each support new statistical analysis if inquired simply as another layer of data. Alternatively, a set of direct track file data plus an ancillary file of derived variables could be generated to support the simulation of an AST prototype system as an overlay on the "truth environment" comprised of VME data.

One can also imagine that the availability of VME measuring equipment may enable certain kinds of experimental measurement that are currently infeasible. For example, a proving grounds experiment of an AST-equipped test vehicle can be conducted coincident with VME measurement on the site in order to quantitatively characterize the actual location of objects and the trajectory of other vehicles in the near-field environment to which the package is currently responding. Without such measurement, the test engineer sees the response of the AST hardware but cannot check the validity of its recorded near-range sensor outputs for lack of a coincident dynamic measurement of the near-range environment itself. Also, it is possible to install the VME measurement equipment in the actual traffic environment in concert with the deployment of vehicles having new IVHS equipment installed. In synchronism with real-time communications to an equipped vehicle, for example, the VME package can characterize any anomalies in driving behavior that ensure from a communication event--all in the context of the rest of the activity occurring within the near-field.

A SYSTEM FOR VME MEASUREMENT

The Vehicle Motion Environment Measurement System (VME-MS) will employ a laser-based three-dimensional imaging sensor working at 10 frames/sec and a general purpose computer processor providing the data on 32 vehicles in a 60' x 200' section of roadway. Co-located with the 3D Laser Sensor will be a CCD camera providing temporally synchronized, backup video, and associated control and processing electronics. This collection of elements is referred to as a Sensor Station. A number of Sensor Stations can be interconnected via a communications network to create the VME-MS whose architecture is illustrated in Figure 3. Control of the VME-MS is centralized as is the data processing that merges the vehicle track data from the individual Sensor Stations. The merging Station is designated the Master Sensor Station. The VME-MS is designed for continuous operation for a 24-hour period, following which the stored data must be removed from the system.

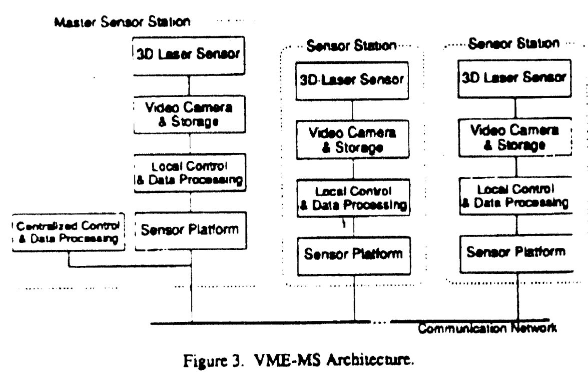

Figure 3. VME-MS Architecture.

The freeway deployment of VME-MS is illustrated in Figure 4. The 3D Laser Sensors view the roadway from the top of a 100 ft. high tower while a weather-proof enclosure at the base contains all electronics needed for control, processing and data recording. The tower is portable for deployment to other sites and is protected by an appropriate vehicle barrier.

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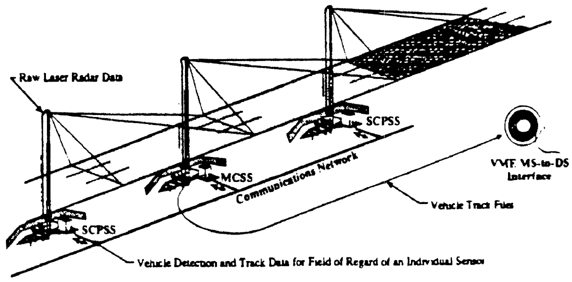

Figure 4. Vehicle Motion Environment - Measurement System (VME-MS).

The deployment of multiple Sensor Stations to cover, for example, a continuous section of freeway or an urban intersection, are shown in Figure 5. For the first implementation of the VME-MS, three Sensor Stations are being built and installation at an urban intersection has been planned.

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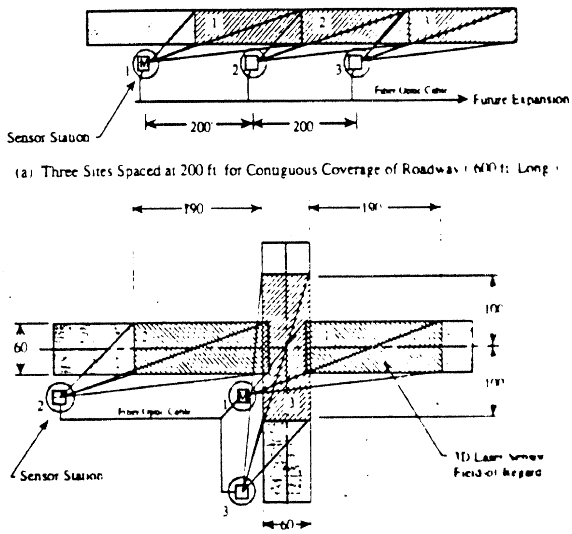

(a) Three Sites Spaced at 200 ft for Contiguous Coverage of Roadway (600 ft Long)

(b) Three Sites Spaced Around Intersection

Figure 5. Multiple VME-MS Sensor Stations Freeway & Intersection Measurement Field of Regard Requirements

The capabilities of the VME-MS are summarized in Table 1 and the major elements of the system are briefly described below.

Laser Sensors

The sensor chosen for the VME-MS is a laser-based, three-dimensional imager, selected because of its superior performance over passive, two-dimensional imagers. The sensor is capable of wide area coverage (i.e., large footprint or field-of-view (FOV)), high spatial resolution (i.e., large number of pixels on target), and very accurate positional measurements. A laser radar provides the following two major advantages, from an image-processing standpoint: (1) it measures actual range to each point in the scene, greatly simplifying the software problem of measuring position; and (2) it provides data that is insensitive to diurnal and seasonal variability

Table 1. Features of the VME-MS.

Coverage Area per Sensor Station	60' wide x 200' long
Number of Sensor Stations	3
Deployment	Along roadway, around intersections, at freeway on/off/merge lanes, etc.
Output Data	Real-time generation of vehicle track files for up to 32 vehicles per sensor station
Data Rate	10 frames/second, 256x128 samples/frame
Data Accuracy	1) X-Y track of vehicle centroid ~ ±6" 2) Vehicle length and width ~ ±3" 2) Yaw angle ± 2° @ 120 ft. slant range Yaw angle ± 8° @ 300 ft. slant range
Coordinate System	Established in the Roadway Surface
Measurement Sensor	Laser-based imaging sensor mounted on 100-ft high, portable tower
Data Processor	Commercial single-board computers
Output Records	1) Track file & incident flags 2) CCD video camera recordings at 5 frames/second for 24 hour operation continuous
Recording Media	1) Magnetic tape for vehicle track files 4) Video cassette for video imagery
Times of Operation	24 hours continuous operations between service for removal of recordings and test of system performance

Generating a 3D Image

A 3D laser radar sensor locates the position of every element in the scene per coordinates of range, azimuth, and elevation. A scene element or pixel is the projection of the laser beam, at an instant in time, on a region of the roadway. The elemental footprint which scans the scene is called the instantaneous field-of-view (IFOV). The scanning concept is depicted in Figure 6.

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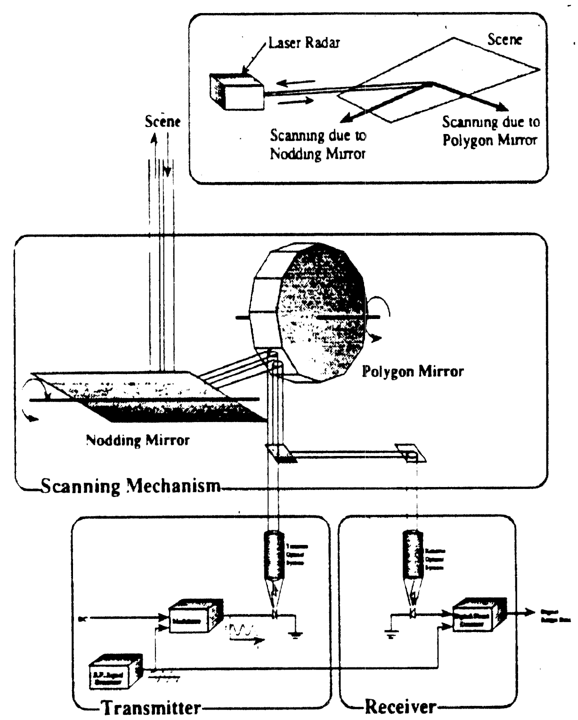


Figure 6. 3-D Laser Radar Sensor Configuration.

The laser beam is caused to scan across the scene (in azimuth, or horizontal, direction) by a high-RPM polygon mirror, one line at a time. The elevation direction is scanned by a nodding planar mirror that shifts to the next elevation pixel at the end of each azimuth scan. Azimuth and elevation are determined according to angular position within the sensor's field-of-view. The sensor will scan the 50° x 25° field of view 10 times per second and will produce 327,680 pixels per second. As shown, the actual area scanned is trapezoidal in shape, containing a 200 ft. x 60 ft. roadway section within this area.

Range to each pixel is determined by measuring the phase shift between the transmitted and reflected laser beams that have been amplitude-modulated by a sinusoidal waveform. The reflectance data can be used to form an image similar to one produced by a conventional video camera. Reflectance data is used in the image and data processing algorithms to aid in resolving occasional ambiguities in the range data. The laser beam divergence angle is 4 milliradian or about 1/4 degree; a pixel at minimum range (~120 ft.) thus covers an areas about 6" x 6" and at maximum range (~350 ft.) it covers approximately 17" x 17." Range measurement accuracy at these ranges for a 20% reflecting surface is calculated to be about 1" and 5" respectively.

Laser Safety Consideration

Laser radiation may harm the eyes and or skin of persons illuminated directly or indirectly by the beam. The level of laser power, the duration of exposure, and the wavelength of the laser combine to determine safe levels of radiation. The American National Standards Institute (ANSI), Inc. has established a full set of regulations to determine safe exposure and procedures for safe operation of all laser systems, both in confined laboratory conditions and in public areas. Using the planned 1 watt laser, calculations show that the hazardous zone for eye exposure extends to 154 ft from the operating sensor. When mounted on a 100 ft tower and oriented with an oblique elevation angle, the nearest roadway intersection with the beam is 175 ft. from sensor, such that the system will satisfy ANSI regulations. Precautions, however, are necessary such as interlock switches to prevent laser operation unless the sensor's scan mirror is rotating and viewing the roadway area of interest.

Platform Subsystem

Deployment of the VME-MS at a variety of roadway locations requires portability of all hardware to support the sensor and associated data processing equipment. Since a variety of sites are necessary and a minimum of seven days are desired at each site, portable platforms are a necessity. Guyed towers have been selected because they can be trailer-mounted and stored in a relatively compact package. The guyed-tower is constructed of multiple telescoping sections which are extended at the site using a powered winch.

The height of the tower is both a critical factor in acquisition of useful imagery and a cost driver in the purchasing and installation of the tower. A nominal height of 100 ft. was chosen as a compromise between a lower tower that would cause considerable vehicle-to-vehicle occlusion effects and a higher tower that could be more costly and difficult to install. The sensor's FOV will be directed as nearly parallel to the traffic lanes as is convenient in order to minimize the extent of lateral occlusion (associated especially with the placement of cars in lanes adjacent to tall semitrailers).

At a maximum range of 300 ft. from the base of the tower, a 13.5 ft. high truck will cast a 41-foot-long shadow along its longitudinal dimension. At a minimum range of 120 ft. the longitudinal shadow length is 16 ft. Occlusion shadows cast horizontally will be a maximum of approximately 8 ft. Based on typical headway distances and velocities, these occlusion zones appear to be acceptable, although passenger cars will occasionally become at least partially occluded at very low speed, and thus, short headways. It is believed that partially-occluded vehicles can be tracked continuously if once viewed full-size although the precision of location will degrade.

Local Control and Processing

The Local Control and Processing Subsystem (LCPS) provides: (1) individual sensor control; (2) real-time image processing of the 3D Laser Sensor data producing up to 32 simultaneous vehicle feature files; and (3) interfaces to both the sensors and the Master Control Subsystem. The LCPS will be implemented using commercially available, single-board computer hardware. The package will be housed in environmental enclosures such as those used for conventional roadside electronics. Coaxial cable, fiber optic and wireless technologies are being evaluated for implementing the local area communications network.

Centralized Control and Processing

The Master Control Subsystem (MCS) will share an environmental enclosure with one of the Local Control and Processing Subsystems. The MCSS provides: (1) the user interface, both local and remote via phone line; (2) real-time data processing of the vehicle feature files to obtain vehicle track files; (3) communications with and control of the individual Local Control and Processing Subsystems; and (4) archival storage of the vehicle track files for a 24-hour period. The Master Control subsystem will also be implemented using commercially available, single-board computer hardware.

Image and Data Processing

During operation of the system, the sensor will quickly acquire both range and intensity images of the open roadway surface and surrounding textures. These images will remain constant until a vehicle enters the scene at which time the difference image may be derived in the data processor for only that region of the scene where the vehicle appears and blocks the roadway surface, thus introducing a change in range to the roadway surface. Real-time image processing is performed at each Sensor Station following which the derived vehicle feature data is transferred to the Master Sensor Station and fused into continuous track files for each individual vehicle. The image and data processing operations are now briefly reviewed.

Real-Time Image and Data Processing

Range and reflectance data from a 3D Laser Sensor will be fed to a dedicated single board computer in each Sensor Station for image and data processing in real time. The output will be in the form of vehicle detections and associated feature lists. The image processing operations involve the detection of all vehicles within each sensors field-of-view. The detection process is based on a change in range from the vehicle-free roadway. Once detection of vehicles has been performed on a frame of data, the image processing tasks are complete, and all further processing is done in terms of individual vehicle detections. As a vehicle moves through one sensor's field of view, there is a need to determine the correspondence between its image taken in one frame and that captured in all other frames where it appeared. This operation will be done as soon as the vehicle has exited from the field-of-view.

There is a need to take the size and shape of each vehicle into account in order to transform the observed centroids into vehicle-centered values. Fortunately, this information is available from the range data that were taken when each vehicle arrived at its closest proximity to the sensor in tower. Knowing which detection in each frame corresponds to a particular vehicle then permits the application of size data in deducing vehicle-centered coordinates.

Retroreflectors will be placed at known locations in the field-of-view of each sensor. The bright return in the reflectance image for these small devices will be readily detected, providing highly accurate feedback of the range viewing angle at which they were observed on each individual frame These will allow dynamic monitoring and modelling of the sensor's attitude, pointing, and location in space. This means that any deflections due to swaying or twisting of the sensor platform can be monitored ten times per second and the results used to improve the accuracy of the track files which are produced.

The operations performed by each Sensor Station are summarized in Figure 7. The feature files from each Sensor Station are transferred to the Master Station for merging into track files for each vehicle.

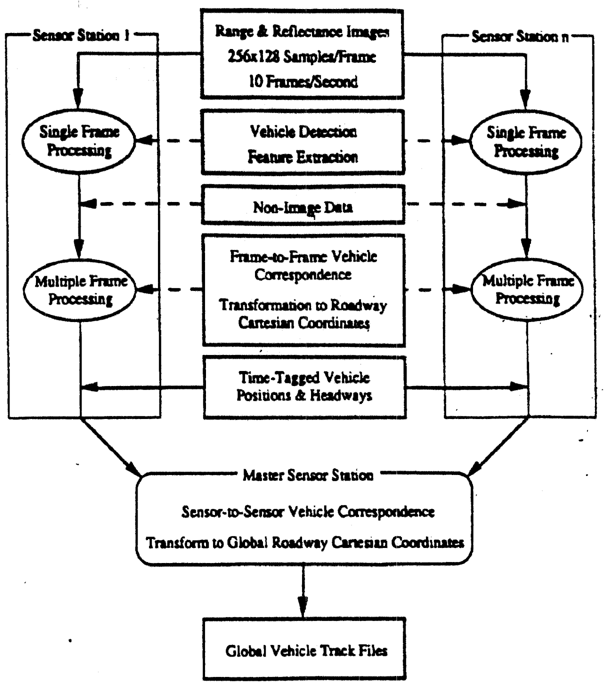


Figure 7. VME Real-Time Image/Data Processing.

Real-Time Feature Data Processing

The MCS processor accepts vehicle track files derived from all sensors once every 0.1 seconds, and has as its primary output vehicle track files taken over the field of regard of the entire ensemble of sensors. Sensor-to-sensor vehicle correspondence is computed within the MCS computer. This approach keeps the data from each Sensor Station independent of one another and allows multiple stations to be employed in various ensembles, for example: (1) all-in-a-row from the same side of a roadway, (2) all-in-a-row on alternating sides of the roadway, (3) viewing the cross-path approaches to an intersection, or (4) spaced out along a continuous section of roadway.

Vehicle track files from a single sensor will be of a variable length that depends upon the number of frames in which the vehicle was observed. An associative memory technique will be employed that allows the most recent n-seconds worth of vehicle track files to be retained in high speed memory and accessed efficiently by pointers. Although each Sensor Station is complete unto itself, the relationship between its own coordinate system and the global reference coordinates is handled by the MCS processor. This processor is also responsible for archiving all VME-MS measurements of vehicle length and width, and the global set of vehicle track files. Here, the associative memory structure mentioned earlier allows all the information pertaining to an individual vehicle to be output as a single structure. In general, the size of this structure is variable depending upon the number of times a vehicle was observed as it passed by the VME-MS.

A VME Data System for Archiving and Processing Track Files

The utilization of track file data will require that such information be efficiently stored, retrieved, and processed in order to serve the applications of the end-user community. In this regard, a flexible VME database is envisioned that would allow track file data to be stored in various formats, depending upon its stage of processing and the particular needs of the database user, or calculated from a built-in method that operates upon track files in their raw (that is, as received from the field) format. The storage formats would encompass these raw track file data as well as fully-processed and enhanced database information obtained from subsequent processing of raw track file data.

The VME database is envisioned at this time as a collection of data files linked together by a software application that permits a broad set of user operations. Consequently, the database will be dynamic insofar as different file formats may be added to the database by use of an accompanying software module that contains methods for extracting, processing, and reviewing the newly-added form of data. Files within the database will also be appropriately tagged to identify the type and nature of data contained in them.

Track Files

Raw track files as produced by the field-deployed VME-MS constitute time histories of forward (x) and lateral (y) displacement of the vehicle's geometric centroid and its angular orientation (yaw angle). Such files need to be organized and archived such that further processing can efficiently extract a wide variety of useful types of information. To facilitate this handling and organization at a data-processing level, each track file will possess a header record containing time of day, date, the length and width of the vehicle's rectangular shadow, notation of any occluded segments in the file and other information pertinent to the vehicle, ambient conditions, and the observation site. Track file names will also be designed to facilitate access to the files and their contents from an operating system level. In addition, an easy-to-use high-level software application will be developed to allow "browsing," statistical data sampling and processing, and for facilitating basic inquiries of the VME database contents.

Figure 8 illustrates the basic concept of a VME database which contains a variety of file formats, including raw track files as well as processed or derived data such as that obtained from scanning all the data using an event detection algorithm. Data handling methods will be contained within the user interface software application.

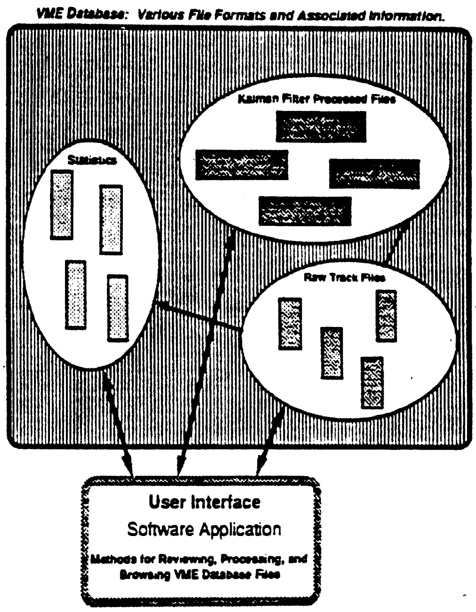


Figure 8. Concept of VME Database and User Interface Program.

Data Processing Issues

Data processing issues that will guide the architecture of the VME-DS arise mainly from the perceived ultimate usage of the VME data. A number of end-uses can operate simply at the level of track file information gathered continuously on all vehicles observed at each measurement site. Track file data from nearby vehicle pairs can also be processed to derive the intervehicular-closure vectors by which vehicles approach one another, the angles of attack relative to vehicle centerlines or road-placed coordinates; the instantaneous clearances, time-to-apparent-collision, etc., as a function of serial time and relative to fixed road features.

Other users may wish to capture only the unusual events or to extract other variables not directly present in the track files such as vehicle yaw rate, body sideslip angles, and driver control inputs of steering and braking. One common inquiry may involve the search for traffic-conflict-type events, or incidents, based upon a running computation using track file variables. For example, a detector algorithm might look for an impending crash condition by noting when the ratio, V/C, exceeds a threshold level -- where V is the closure or relative velocity between two nearby vehicles and C is the instantaneous clearance distance between them.

To expand upon the variables present within an individual track file, it is possible to apply (with varying degrees of accuracy) a relatively common signal processing scheme known as Kalman filtering.[1, 3, 4] The basic idea behind Kalman filtering is to combine knowledge of the dynamics of the system being observed (i.e., the vehicle dynamics in this case) with a sequence of measurements of that system over time. Knowledge of the approximate system dynamics permits the likely estimation of the system motion over time, while the direct sequential measurements provides a correcting mechanism based upon relative accuracies assumed for the sensors versus that assumed for the system dynamics. In essence, the Kalman filter employs an internal model (usually in a simplified form) of the system being measured and utilizes that model in combination with the measured data to obtain a best estimate of the system behavior from measurement to measurement.

As a supplement to VME processing, the Kalman filter technique becomes feasible insofar as the data on length and width of each vehicle roughly establishes its type and especially with passenger cars -- its weight and principal moments of inertia. Since all road vehicles run on pneumatic tires and, thus, exhibit certain normalized properties in their horizontal plane dynamics, it is possible to define a reasonable first-order estimate of the vehicle model needed for exercising the Kalman filter. When specific vehicles are to be modelled with more precision such as in reconstructing a crash or near-miss event, examination of footage from the accompanying video camera may help in further identifying make and model. An example application of Kalman filtering to a simulated set of VME data was reported.[1]

At perhaps the highest level of VME utilization, one could simulate the operation of a concept AST package, using a combination of VME variables as the truth environment. For example, a run-off-road warning system being developed in the future may require on-board signals representing steering wheel angle, forward speed, and yaw rate as well as sensory signals showing vehicle position and heading angle relative to the upcoming lane edge. The VME data file could support a simulation of this system by generating a continuous data set containing each of these variables for each "host vehicle" that was observed by the VME roadside measurement package. Occlusion of the sensor's view of the lane edge by vehicles just ahead of the host vehicle could be represented in this example by computing the orientation of sensing shadows cast by the preceding vehicles having contemporaneous track files.

A running computation of the response of the simulated warning system on many thousands of vehicles passing through various sites would render a clinical, repeatable assessment of the system's performance as regards the influence of driver control activity, geometric variables, and motions of the host vehicle and others nearby. Where anomalies in the response of the simulated system are observed, the cases in question can be flagged for more detailed follow-up analysis.

Accordingly, it is clear that a variety of post-processing programs and algorithms are likely to have value, each tailored to specific types of application. Enriched data files, representing either statistical measures or complete time histories of driver control responses, must be accessible within the VME database either from a built-in, command-driven process or from an augmented database containing the additional derived data.

REFERENCES

1. Ervin, R.D., MacAdam, C.C., Gilbert, R.K., and Tchoryk, P., "Quantitative Characterization of the Vehicle Motion Environment (VME)," SAE Paper No. 912854, *Proceedings of the Vehicle Navigation and Information Systems Conference*, Dearborn, Michigan, 1991.

2. "NHTSA IVHS Plan," Planning Document of the National Highway Traffic Safety Administration, U.S. Dept. of Transportation, June 1992.

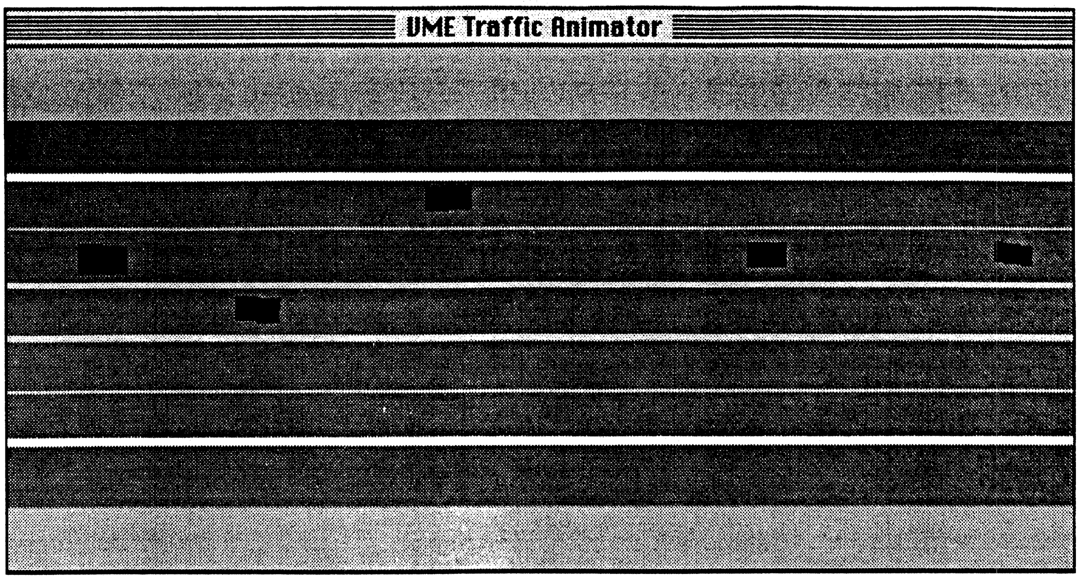
3. B. W. Leach, *An Introduction to Kalman Filtering*, 1984.

4. K. S. Miller and M. S. Leskiw, *An Introduction to Kalman Filtering with Applications*, Robert E. Kreiger Publishing Co., Malabar, Florida, 1987.

Appendix C

VME-DS Design — User's Guide and Pre-Processor Documentation

This Appendix contains inital versions of the VME-DS User's Guide and the VME Pre-Processor Guide by Kevin O'Malley.



VME-DS

User's Guide

Version 1.0

VME-DS for Macintosh™ User's Guide

by Kevin O'Malley and Charles MacAdam

VME-DS is provided "as-is", without warranty. We assume no responsibility for any errors, or for damages resulting from the use of the information contained herein.

VME-DS for the Macintosh
User's Guide

Contents

VME-DS for the Macintosh

Getting Started

- Introduction
- What you should know
- System Requirements
- Installation
- Technical Support

Getting Started

Introduction

VME-DS processes libraries of VME track files and allows users to view data in a variety of formats (text files, graphs and animation's). The VME-DS also supports certain types of processing calculations on the raw track file data (smoothing, Kalman filtering, etc.). Special calculations are also included to allow users to conduct crash detection / near-miss calculations, or, to export files of more detailed information on each vehicle's motion experience (e.g., range and angle-of-attack data for each vehicle pair in the field of regard). These latter data can then be further processed and analyzed with commercially available statistical analysis programs or other analysis tools to obtain histograms and other specialized plots describing the motion experiences of the selected files. Additional specialized calculation modules may be added subsequently depending upon anticipated needs.

What You Should Know

This manual assumes that you know, or are learning, how to use a Macintosh Computer with System 7 or greater. If you encounter any problems using your Macintosh, please see your Macintosh User's Guide.

System Requirements

VME-DS runs on Macintosh's equipped with System 7 or greater. Table 1 summarizes the requirements.

Table 1. System requirements for VME-DS

Feature	Status	Requirement
CPU	Required Recommended	Macintosh with 68030 Macintosh with 68040
Co-processor	Recommended	Math co-processor
Operating System	Required	System 7 or greater
RAM Memory	Required	8 MB or more
Hard Disk Space	Required	250 KB free or more
Media	Required	3.5" floppy drive
Monitor	Required	
Printer	Recommended	

Installation

To install VME-DS from the VME-DS distribution disk, simply drag the folder VME-DS to your hard disk. The VME-DS folder contains the following folders and files:

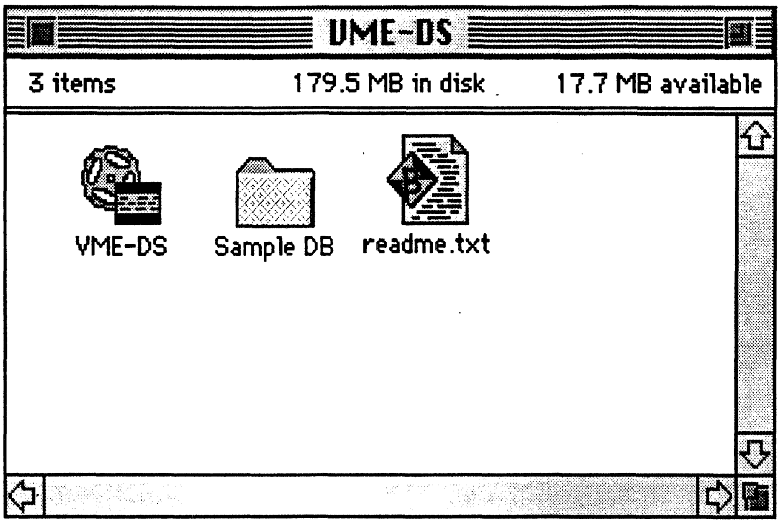


Figure 1

VME-DS Folder

Technical Support

Help is available on-line within the VME-DS program. This provides help with the most common problems. If further assistance is necessary, contact us via e-mail, providing the following information:

- Version number and date of VME-DS (found in the About Box)
- A description of the problem, including what occurred and any error messages that were displayed
- Information on the system that was being used when the problem occurred

Internet: omalley@umich.edu.

VME-DS for the Macintosh

Tutorial

- Opening a Database
- Searching the Database
- Viewing Search Results

Tutorial

Use this tutorial to familiarize yourself with the features and abilities of VME-DS. Using the sample database (`DBFile`) included on the VME-DS distribution disk, you will learn the process of opening a database, searching the database and viewing the results. This tutorial covers the following topics:

- Opening a database
- Searching the database
- Viewing the search results

Opening a Database

To begin using VME-DS open the folder which contains the VME-DS program and double click on the VME-DS icon.

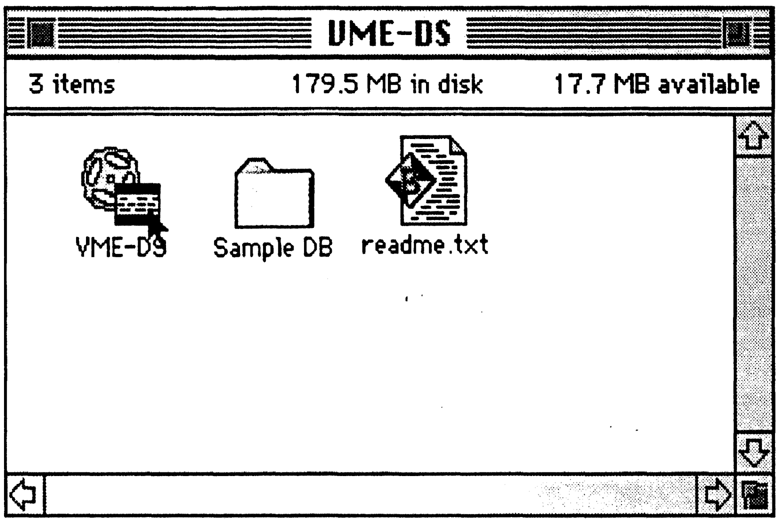


Figure 2

Launching the VME-DS program

Once the program is loaded, select **Open Database...** from the **File** menu.

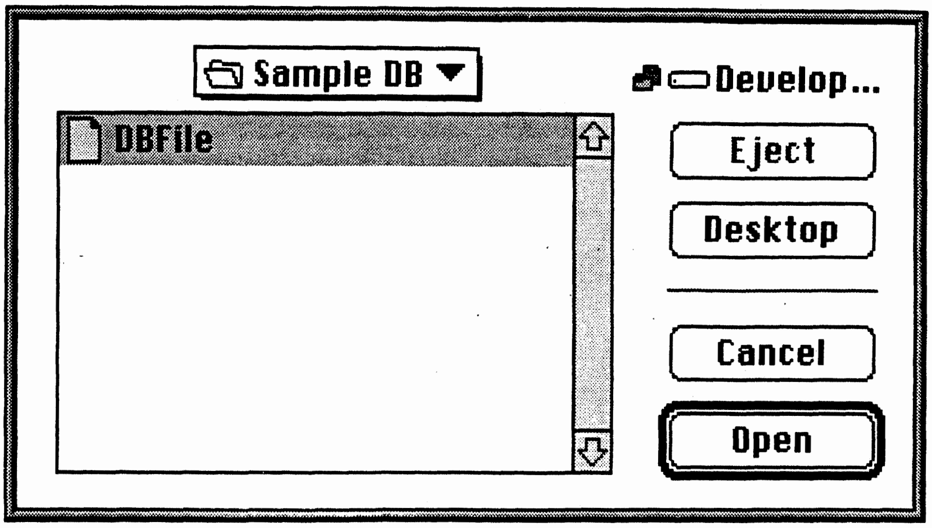


Figure 3

Open File Dialog

The open database dialog lists the track file database files accessible to the program. Navigate to the `Sample DB` folder (located within the installation VME-DS folder), select the file `DBFile` and click the Open button. The database is now available for use.

Searching a Database

Select **Find...** from the **Edit** menu. This command displays the Search Manager dialog.

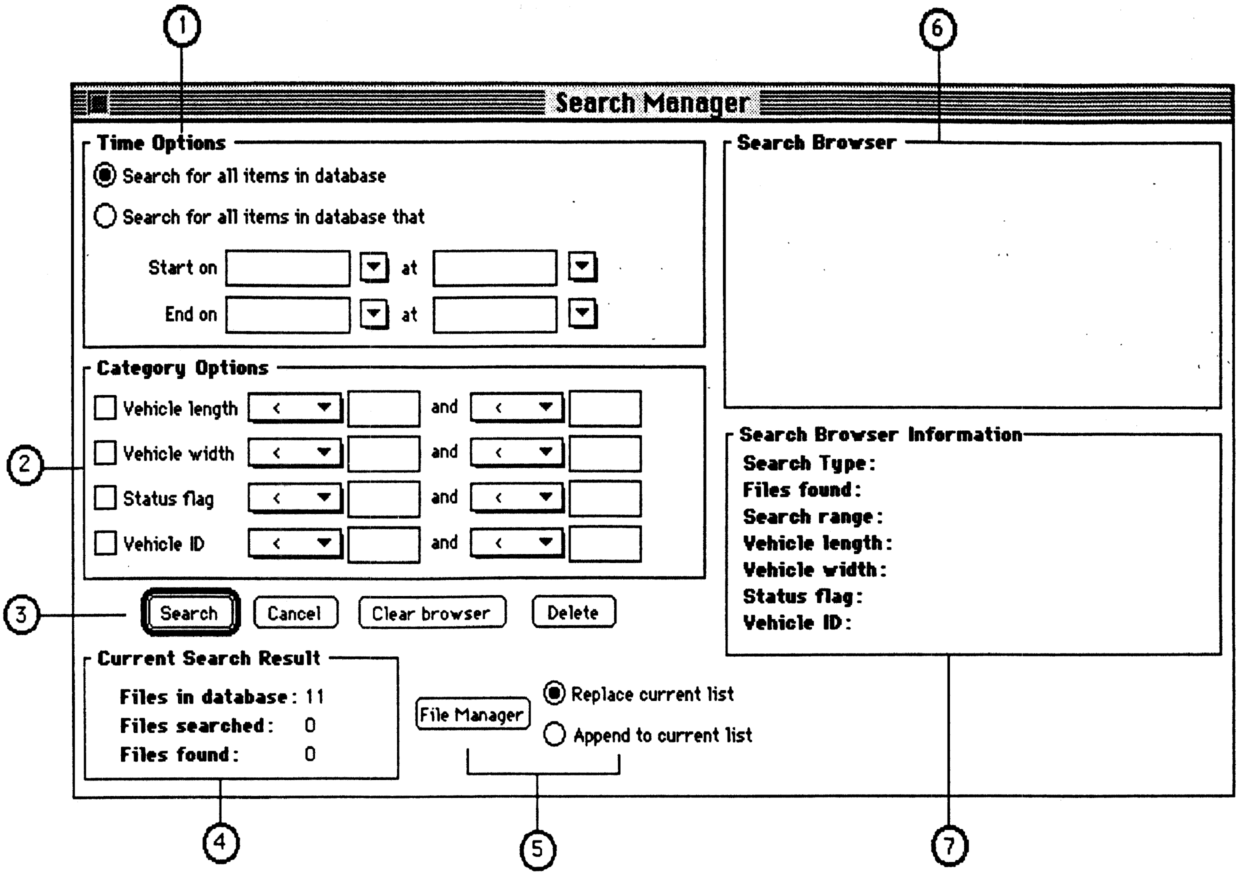


Figure 4

Search Manager Dialog

The Search Manager is used to enter search criteria and search the database. Table 2 summarizes the Search Manager dialog options.

Table 2. Search Manager Dialog Options

No.	Dialog Item	Description
1	Time Options	<u>Search for all items in database</u> Select this button to search all files in the database <u>Search for all items in database that</u> Select this button to search for files within a date/time range
2	Category Options	<u>Vehicle Length</u> Specifies the vehicle length range <u>Vehicle Width</u> Specifies the vehicle width range <u>Status Flag</u> Specifies the status flag range <u>Vehicle ID</u> Specifies the vehicle id range

3	Command Buttons	Search Press this button to search the database for the selected criteria Cancel Close the search dialog Clear Browser Clears the current search browser Delete Delete the selected search node
4	Current Search Results	Displays the result of the current search
5	File Manager Copy Options	File Manager Press this button to copy the selected search node to the File Manager Replace List Replaces the current contents of the File Manager list with the selected search Append to List Appends the current search to the contents of the File Manager list
6	Search Browser	Displays the results of all searches
7	Search Browser Information	Displays information for the selected search node

Search Types

The Search Manager supports two types of searches: (1) Primary searches and (2) Sub-searches. A primary search is defined as a search of the database that is not based on a previous search. A sub-search is a search which is based on a previous search. To perform a primary search make sure that no search node is selected in the Search Browser. To perform a sub-search, select a search node item from the Search Browser list.

For our first search example, we will conduct a primary search of the database for all entries whose vehicle length is greater than 11 and less than 22. Select the Vehicle Length checkbox, select the greater than symbol from the corresponding popup menu and type in 11, then select the less than symbol from the next popup menu and type in 22. Click on the Search button.

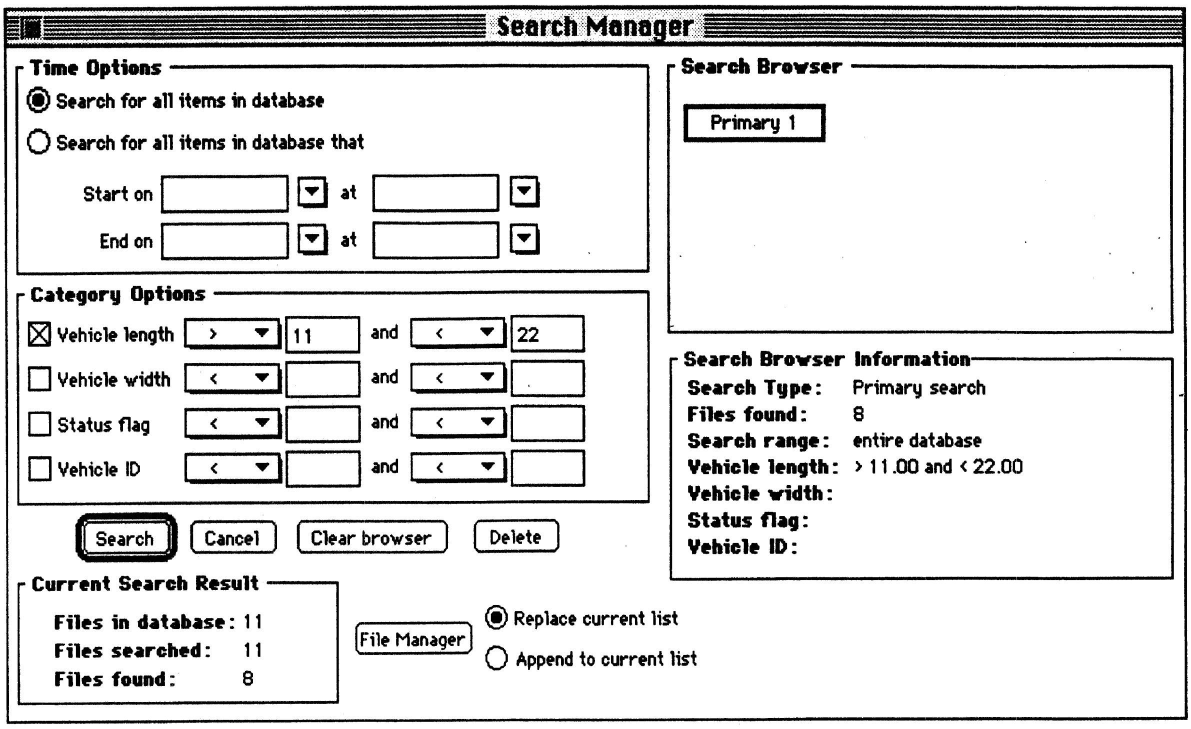


Figure 5

Primary Search Results Window

The Search Browser displays the results of the search. The search node displayed in the Search Browser shows that the search was a primary search. Search Browser Information displays detailed information for the selected search node. Current Search Result displays the number of files in the database, the number of files searched and the number of files found. For this search, 11 files track files are in the database, 11 files were searched and 8 files were found

For our next example we will conduct a sub-search for entries whose vehicle width is greater than 4 and less than 7. Make sure the primary search node is selected from the Search Browser and select the Vehicle Width checkbox. Select the greater than symbol from the corresponding popup menu and type in 4, then select the less than symbol from the second popup menu and type in 7. Click on the Search button.

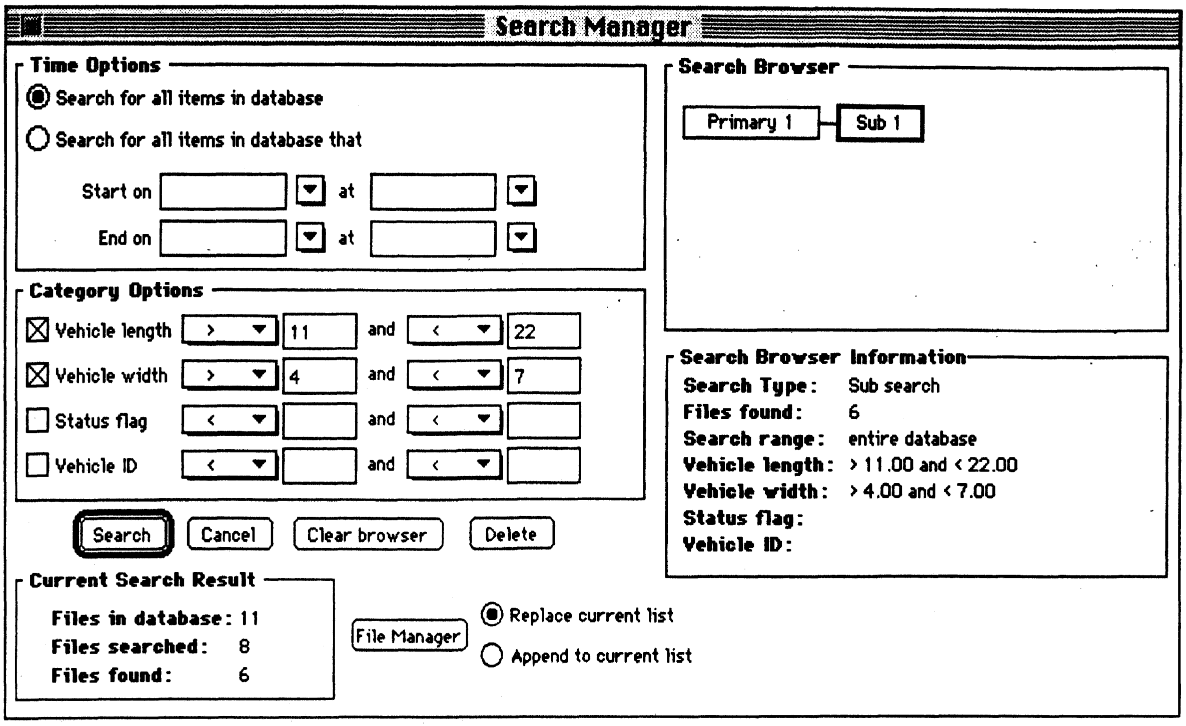


Figure 6

Sub-Search Results Window

The Search Browser list displays the result of the sub-search. In this case, the sub-search searched 8 track files and found 6 matches in the range that matched the search criteria.

To display information for each search click on a search node in the Search Browser. The information for the selected search node will be displayed in the Search Browser Information section of the dialog.

Sub-Searching give you the ability to begin with a general search and, through sub-searching, narrow your search down.

Viewing Search Results

Once you have performed one or more searches you can choose a analysis tool to view the results. Select the first search node (Primary 1) from the Search Browser and press the File Manager button. This will copy the files found from that search to the File Manager window.

The VME File Manager collects search results and allows you to choose an analysis tool to view the results. Table 3 summarizes the VME File Manager dialog options.

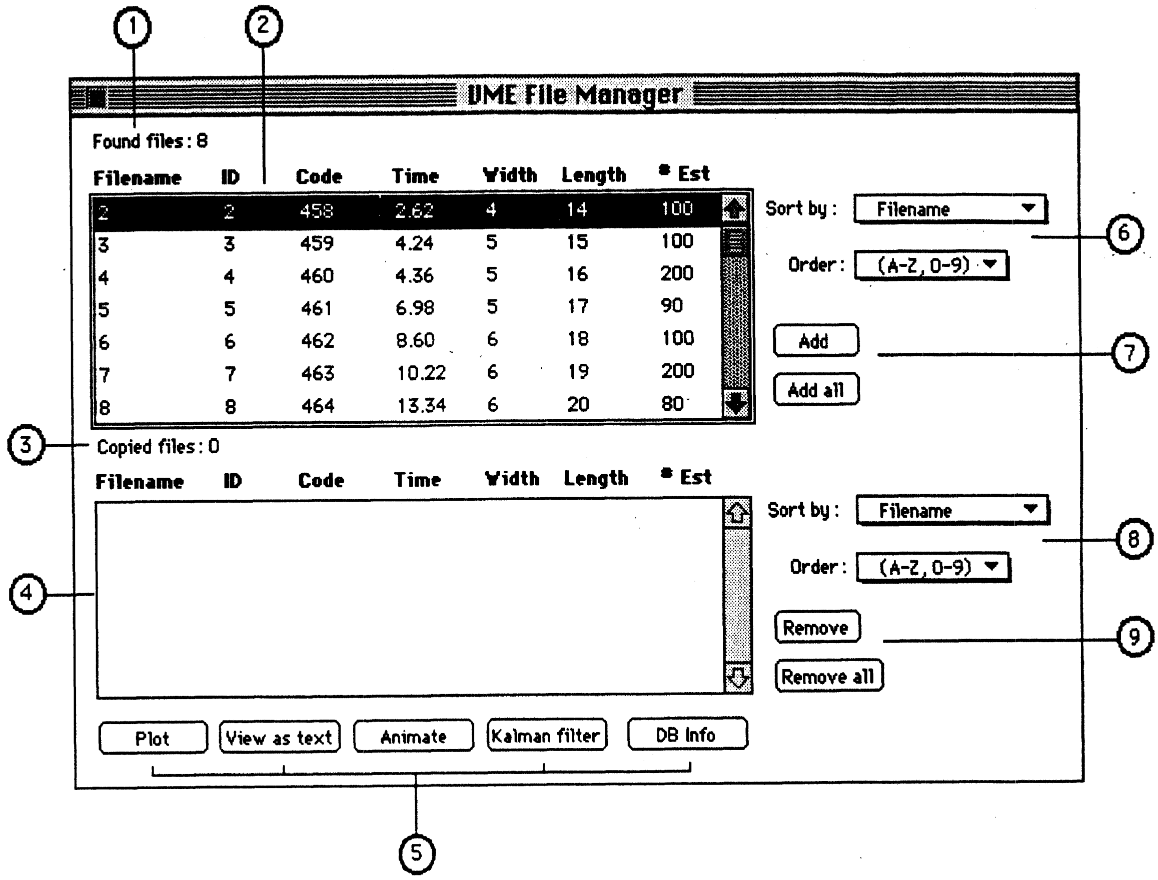


Figure 7

File Manager Window

Table 3. File Manager Dialog Options

No.	Dialog Item	Description
1	Found Files	Displays the number of files in the found list
2	Found List	Displays the files found in the search
3	Copied Files	Displays the number of files copied from the found list to the analysis file list
4	Analysis List	Displays the files copied to the analysis list
5	List Buttons	Plot Plot all files in the analysis list View as Text View the selected file in the analysis list Animate Animate all files in the analysis list Kalman Filter Filter all files in the analysis list DB Info Display information for the current database

6	Found List Sort Options	Sorts files in the found list Sort By Popup menu used to select sort options Sort Order Popup menu used to select sort order options
7	Found List Buttons	Add Add the hilighted file to the analysis list Add All Add all files to the analysis list
8	Analysis List Sort Options	Sorts files in the analysis list Sort By Popup menu used to select sort options Sort Order Popup menu used to select sort order options
9	Found List Buttons	Remove Remove the hilighted file to the analysis list Remove All Remove all files to the analysis list

Animating Search Results

The VME File Manager window displays the files found from the selected search. The first tool we will use is the animator. Select the Add All button. This will copy all files in the found list to the analysis list.

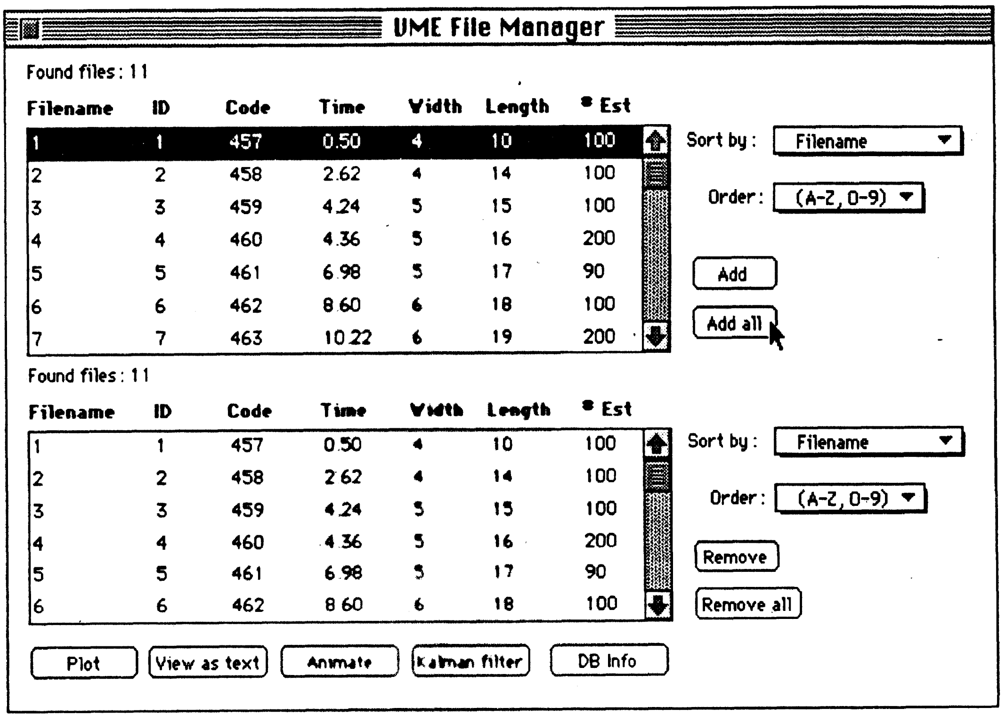


Figure 8 - VME File Manager After Add All

Next, select the Animate button.

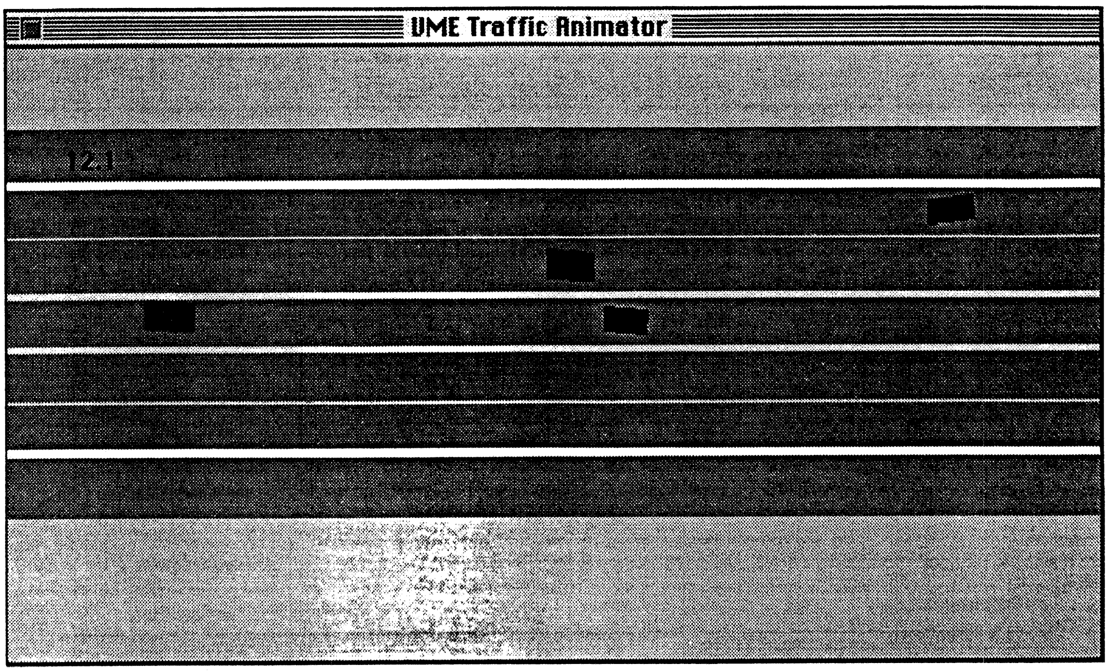


Figure 9

VME Traffic Animator Window

The Traffic Animator window is displayed and an animation of the selected files is shown. The animator module permits the user to animate sequences of track files on-screen as a simplified traffic flow. This feature can be useful for viewing the basic dynamic interactions of vehicles as they move through the field of regard. The on-screen movie can be started from various reference times and will play continuously until interrupted by the user. A time-base or clock reference is also seen on screen during the animation to help identify and locate which track files of the database are currently being observed.

To end the animation press the mouse button anywhere in the VME Traffic Animator window. Close the windows and return to the VME File Manager.

Plotting Search Results

To plot the files click the Plot button. This opens the VME Plot Manager and loads the selected files into the plotter. Table 4 summarizes the VME Plot Manager dialog options.

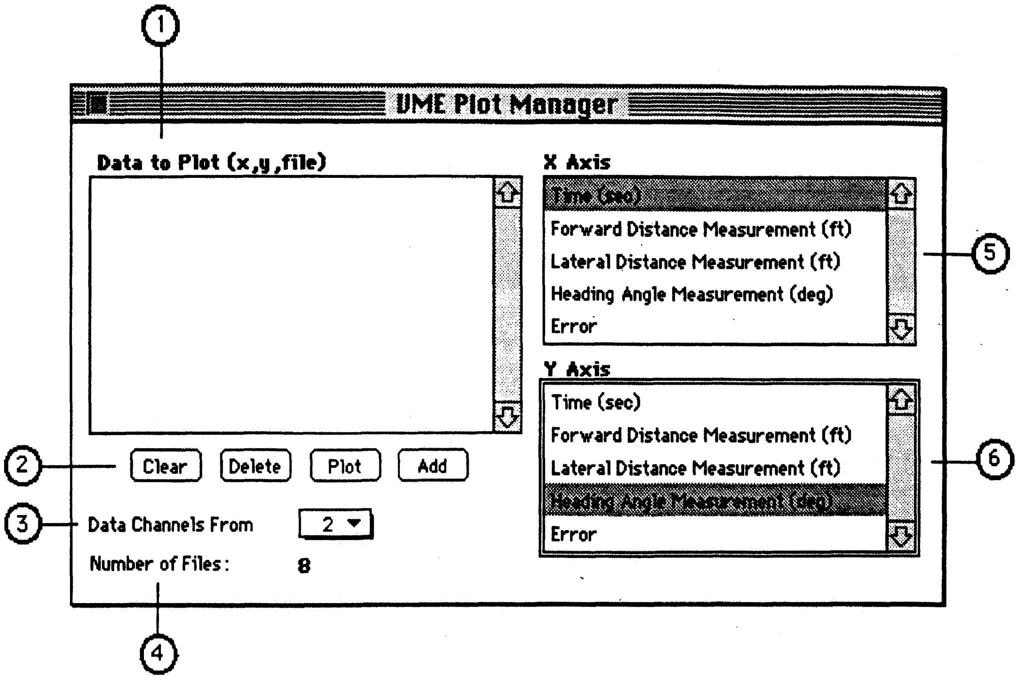


Figure 10

VME Plot Manager Window

Table 4. File Manager Dialog Options

No.	Dialog Item	Description
1	Data to Plot	Displays the selected channels to plot.
2	Plot Buttons	<u>Clear</u> Clear all files in the data to plot list <u>Delete</u> Delete the selected file from the data to plot list <u>Plot</u> Plot all channels in the list <u>Add</u> Add the selected channels to the data to plot list
3	Data Channels From	Displays a popup menu of found files
4	Number of Files	Displays the number of files in the popup menu
5	X Axis	X channel list
6	Y Axis	Y channel list

Select Time vs. Heading Angle Measurement (deg) and press the Add button. The selected channels are added to the Data to Plot list.

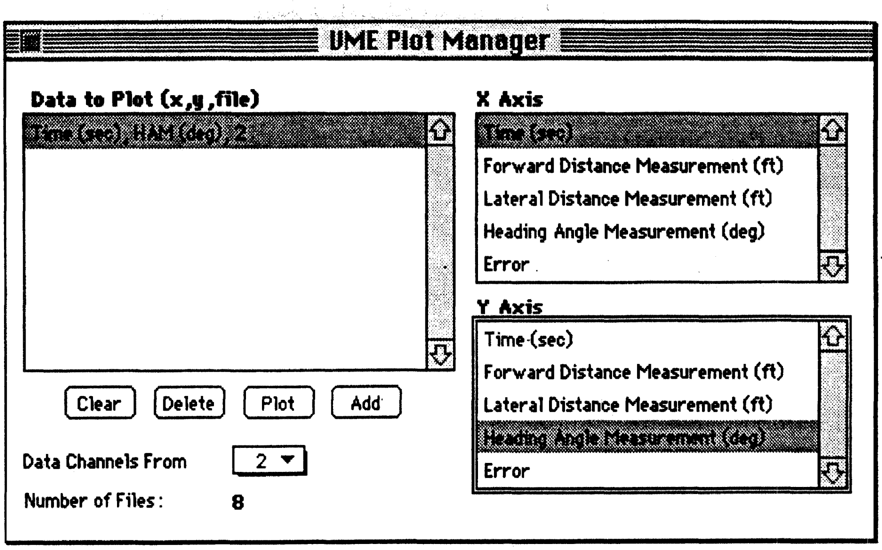


Figure 11

Plotter Channel Select Window

Press the Plot button to display the plot.

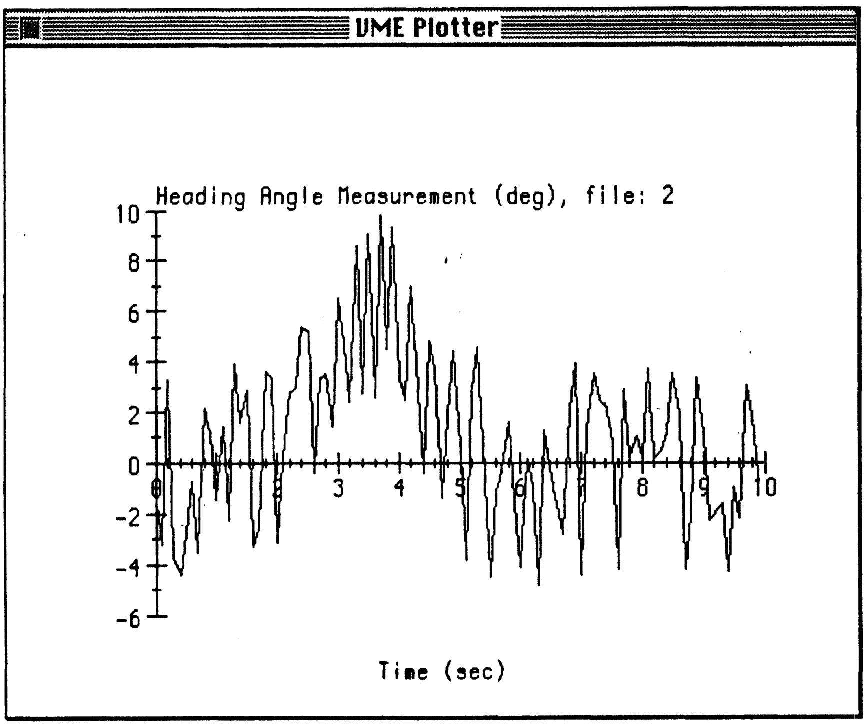
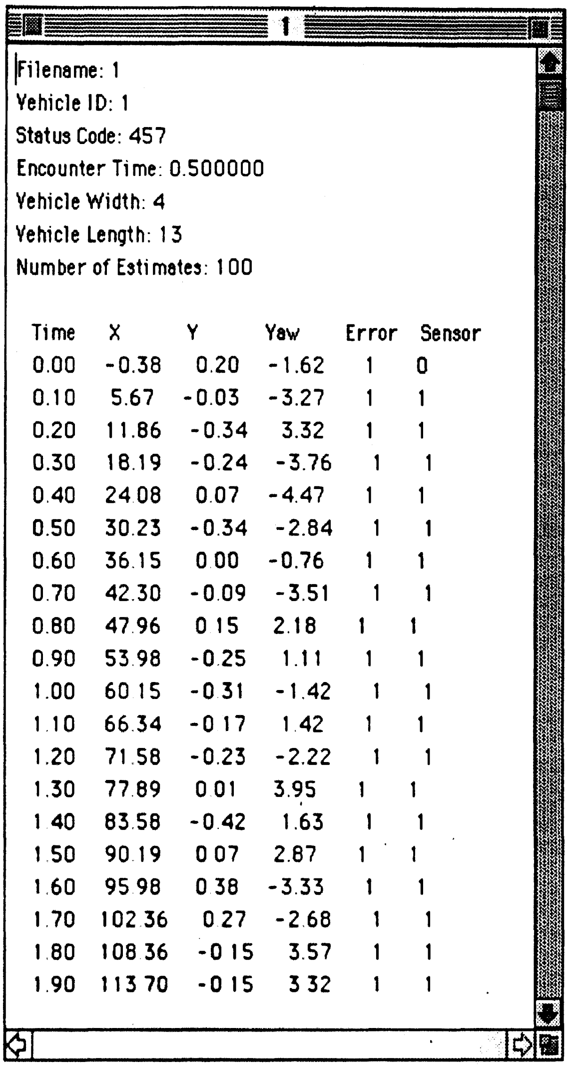


Figure 12

Plot Display Window

Viewing Search Results

Close the window and return to the VME File Manager. The text editor component permits the user to view one or more track files as an ordinary text file comprised of the header information and the track file measurements listed as time histories. Select the first file from the analysis list and click the View As Text button.



Filename: 1
Vehicle ID: 1
Status Code: 457
Encounter Time: 0.500000
Vehicle Width: 4
Vehicle Length: 13
Number of Estimates: 100

Time	X	Y	Yaw	Error	Sensor
0.00	-0.38	0.20	-1.62	1	0
0.10	5.67	-0.03	-3.27	1	1
0.20	11.86	-0.34	3.32	1	1
0.30	18.19	-0.24	-3.76	1	1
0.40	24.08	0.07	-4.47	1	1
0.50	30.23	-0.34	-2.84	1	1
0.60	36.15	0.00	-0.76	1	1
0.70	42.30	-0.09	-3.51	1	1
0.80	47.96	0.15	2.18	1	1
0.90	53.98	-0.25	1.11	1	1
1.00	60.15	-0.31	-1.42	1	1
1.10	66.34	-0.17	1.42	1	1
1.20	71.58	-0.23	-2.22	1	1
1.30	77.89	0.01	3.95	1	1
1.40	83.58	-0.42	1.63	1	1
1.50	90.19	0.07	2.87	1	1
1.60	95.98	0.38	-3.33	1	1
1.70	102.36	0.27	-2.68	1	1
1.80	108.36	-0.15	3.57	1	1
1.90	113.70	-0.15	3.32	1	1

Figure 13

Editor Window

The header information and track file measurements listed as time histories are displayed in the editor. This file can be viewed, saved or printed.

Viewing Database Information

Close the window and return to the VME File Manager. To view information for the current database, click the DB Info button. This displays information for the current database.

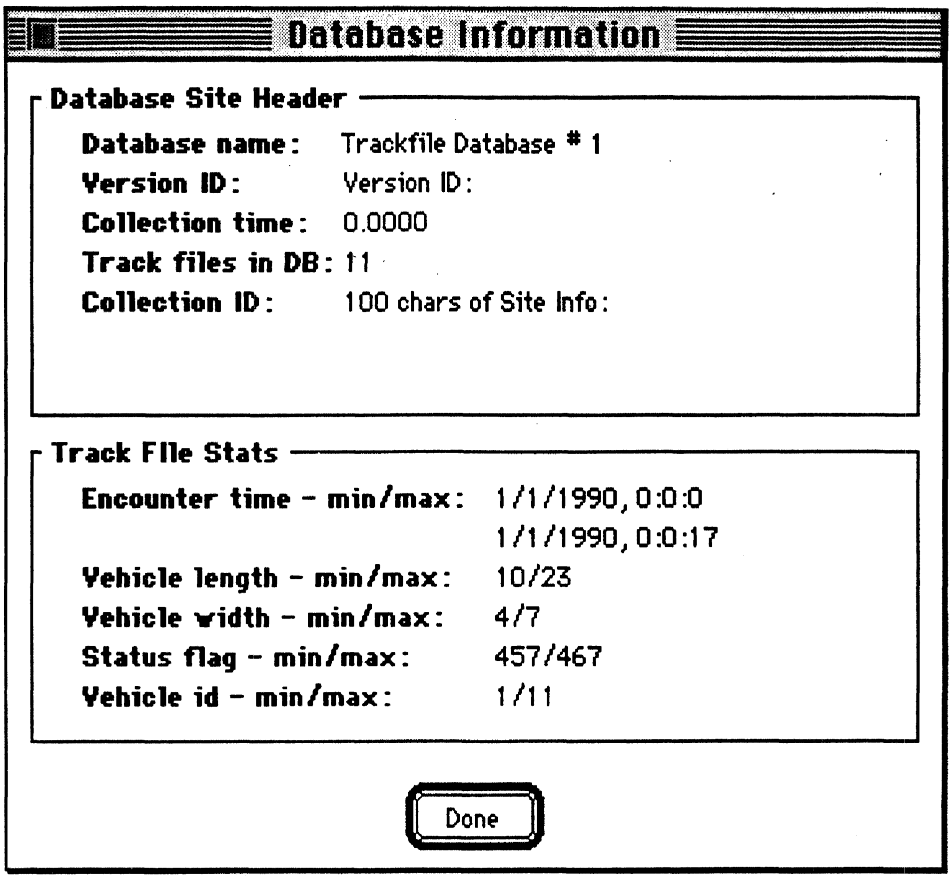


Figure 14

Database Information Window

Filtering Search Results

Close the window and return to the VME File Manager. The Kalman filter module applies calculation to the selected file and extracts five additional driver/vehicle response time histories. The Kalman filter calculation is tuned to vehicle size and speed using information contained in the track filer header record (vehicle length parameter and initial speed of entry into the field of regard). The Kalman filter calculations utilize a simple 3-degree of freedom vehicle model comprised of lateral translation, longitudinal translation, and yaw (heading) rotation. In addition to the three signals being directly measured by the sensor package and constituting the primary track file information: forward displacement (x), lateral displacement (y), and heading angle (psi), the Kalman filter also estimates five additional driver/vehicle system response variables. These are: forward speed, lateral speed, yaw rate, front wheel steer angle, and longitudinal acceleration. The latter two response variables, front wheel steer angle and longitudinal acceleration, represent driver control response inputs to the vehicle required to achieve the vehicle responses reflected in the x, y, and heading measurements. The output from the Kalman filter also produces improved estimates for the three measured states (forward position, lateral position, and heading angle. Consequently, the total output from the Kalman filter calculation is an 8-state vector comprised of: longitudinal vehicle position, lateral vehicle position, vehicle heading angle, forward vehicle speed, lateral vehicle speed, vehicle yaw rate, front wheel steer angle (driver), and longitudinal acceleration (driver).

To filter and view the files click the Kalman Filter button. This opens the Kalman Filter dialog and loads the selected files into the filter list. The selected files are copied to the Kalman Filter dialog. Table 5 summarizes the Kalman Filter dialog options.

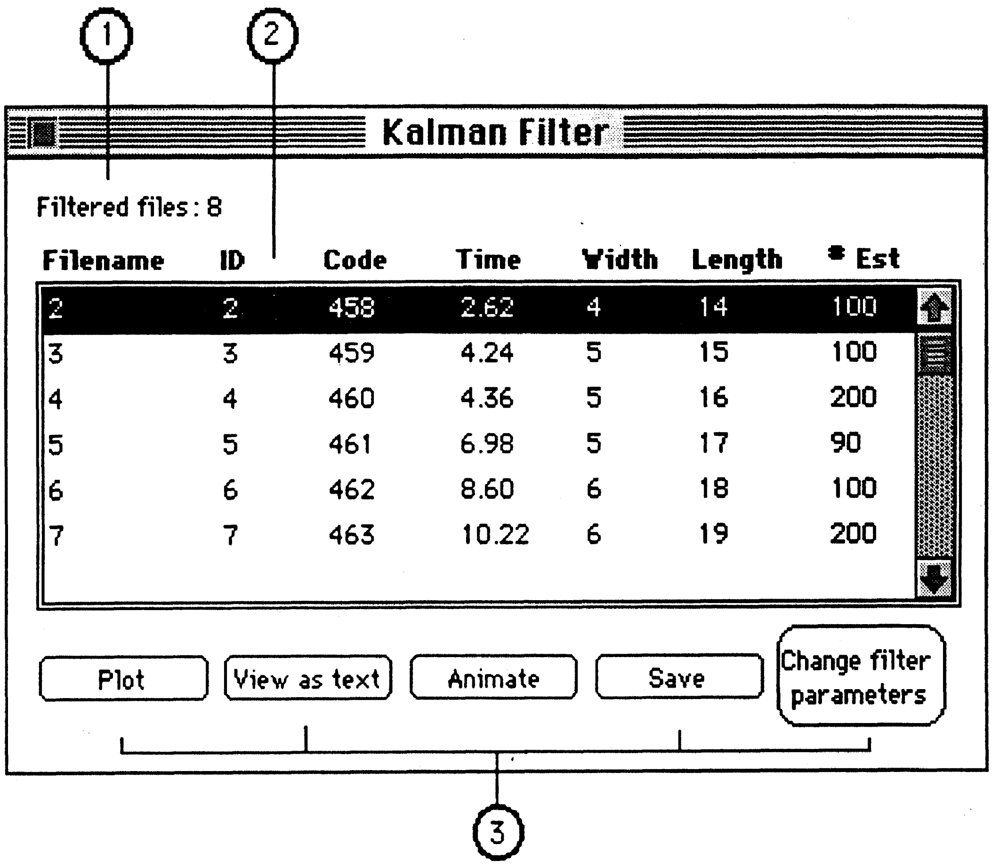


Figure 15

Kalman Filter Dialog

Table 5. Kalman Filter Dialog Options

No.	Dialog Item	Description
1	Filtered Files	Displays the number of filtered in the list
2	Filtered List	Displays the filtered files
3	List Buttons	Plot Plot all files in the analysis list View as Text View the selected file in the analysis list Animate Animate all files in the analysis list Save <> Change Filter Parameters <>

Select the first file in the list and click the Plot button.

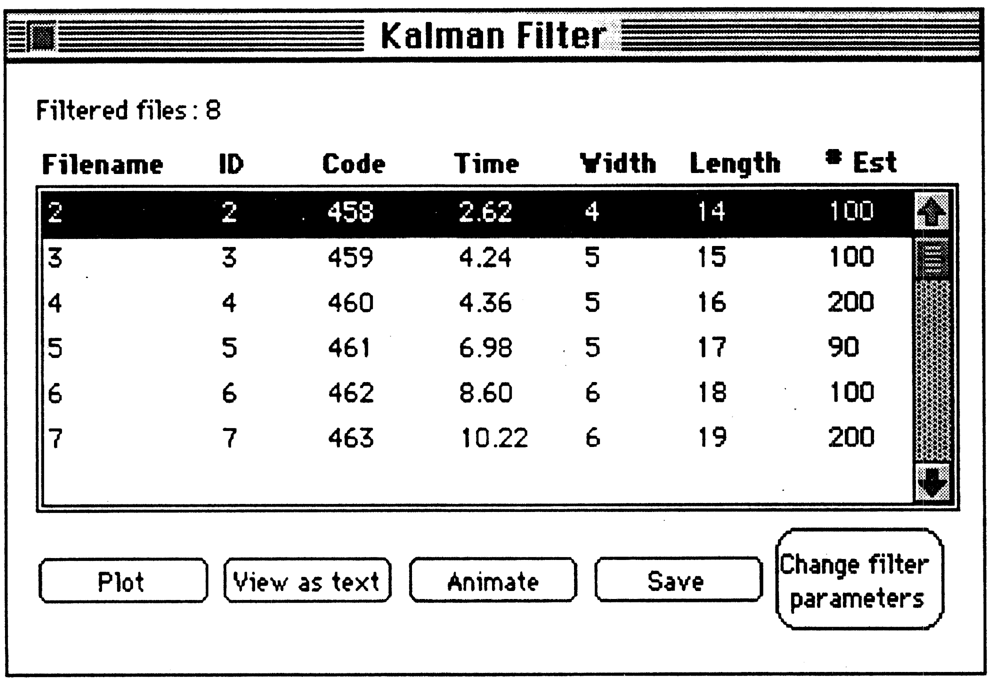


Figure 16

Kalman Filter Dialog

Select Time vs. Lateral Distance Measurement (ft) and press the Add button. Next, select Time vs. Lateral Distance Filter Estimate (ft) and press the Add button. The selected channels are added to the Data to Plot list.

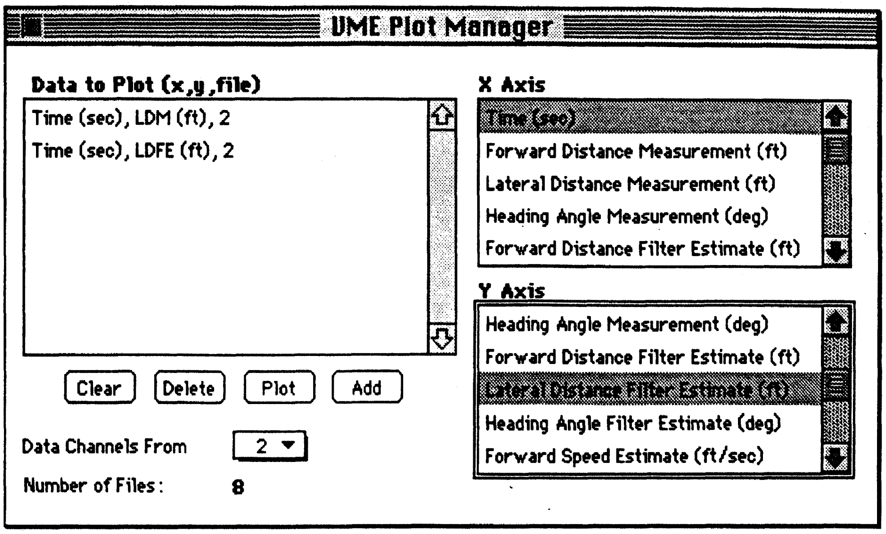


Figure 17

Plot Manager For Filtered Data

Press the Plot button to plot the raw vs. filtered data.

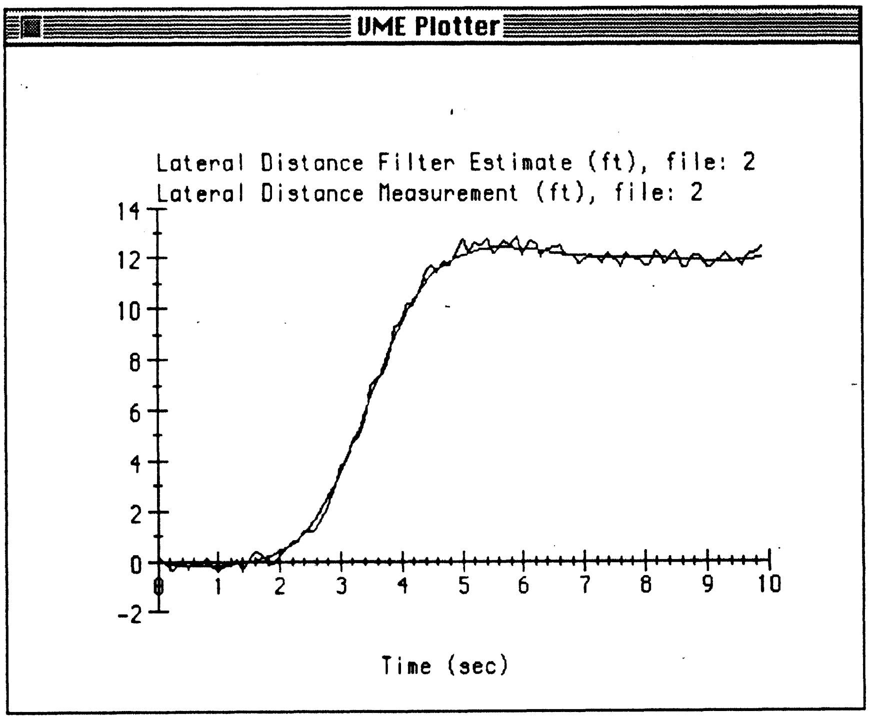


Figure 18

Plot of Raw vs. Filtered Data

Special Calculation Modules

The Special Calculations menu contains menu items that perform specialized calculations applicable to larger groups of track files. At the present, two special calculation modules are available - one for detecting crash events, the other for computing large quantities of inter-vehicular spacing information (time histories of range and angle-of-attack between all vehicles within the field of regard at each sample time).

Crash Detection

The Crash Detection special calculation module calculates the inter-vehicular gap between adjacent vehicles at each instant of time within the field of regard. As the traffic flow proceeds and gap calculation that falls below a specified threshold set by the user will be tagged and recorded to disk file for later review. An option to view an animation of the traffic as the crash detection calculation occurs is also available. Under this option, a crash event will cause the two intersecting vehicles to change color and thereby assist the user in detecting the computed crash event on screen.

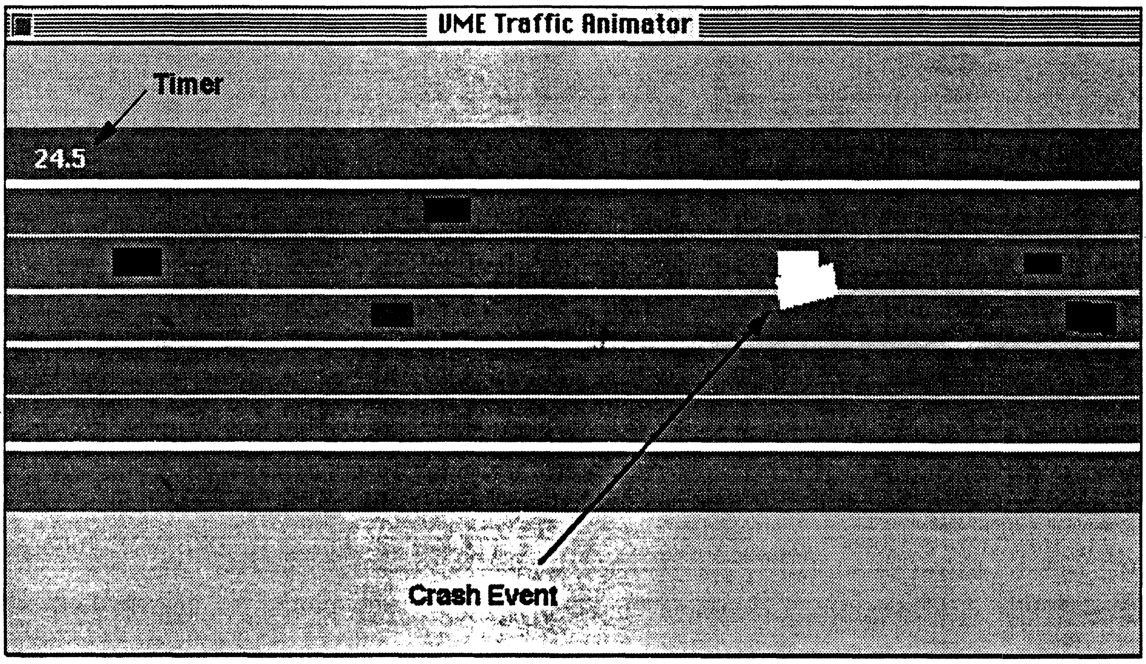


Figure 19

Crash Detection Calculation and On-Screen Display

Inter-Vehicular Variables

Under the Computation of Inter-vehicular Variables special calculation, the range and angle-of-attack between any two vehicles within the field of regard are computed and exported to a disk file. This computation occurs for each vehicle pair and for each sampling time during a time period specified by the program user.

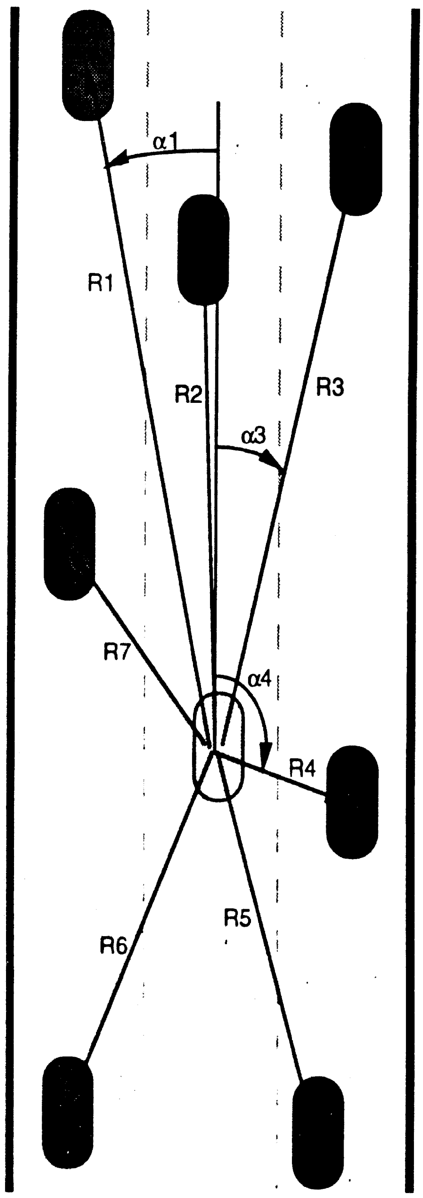


Figure 20

Range and Angle-of-Attack Variables Calculated as Inter-Vehicular Variables

VME-DS for the Macintosh

Menus

- File menu
- Edit menu
- Special menu
- Windows menu

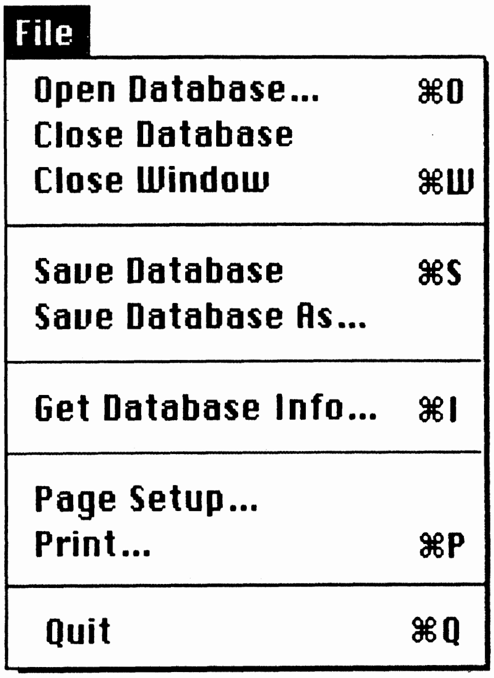
VME-DS Menus

The Apple Menu

About VME-DS...

The **About VME-DS** command tells what version of the program is being used, as well as basic program information.

The File Menu



The file menu is used to perform application filing options, such as opening and closing database files. This menu also has the command which allows you to quit the program.

Open Database...

The open command displays a dialog box that lets you choose a Track file database to open.

Close Database...

The close database command closes the currently opened Track file database.

Close Window...

The close command closes the front-most window.

Save Database

The save database command is used to save any modifications to the current database.

Save Database As...

The save database as command is used to save the current database under a new name. The original database is left untouched.

Get Database Info...

This command is used to display information for the current database.

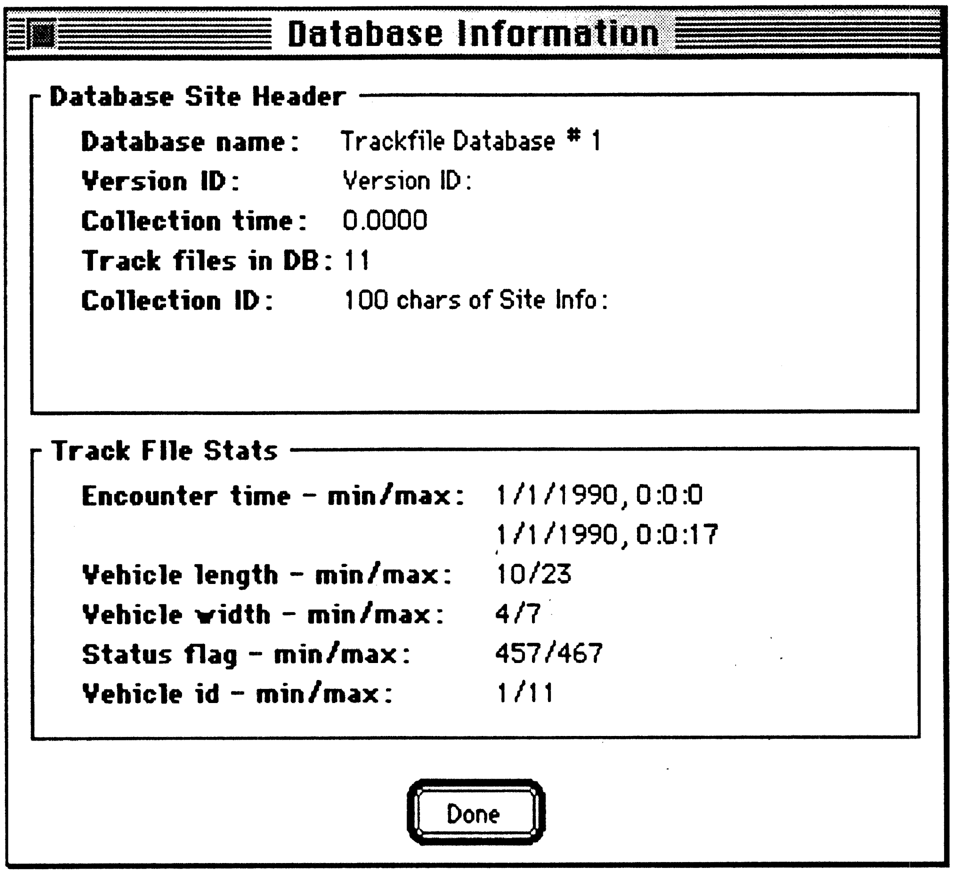


Figure 21

Database Information Dialog

Page Setup...

This command lets you specify printing parameters which control the printed document.

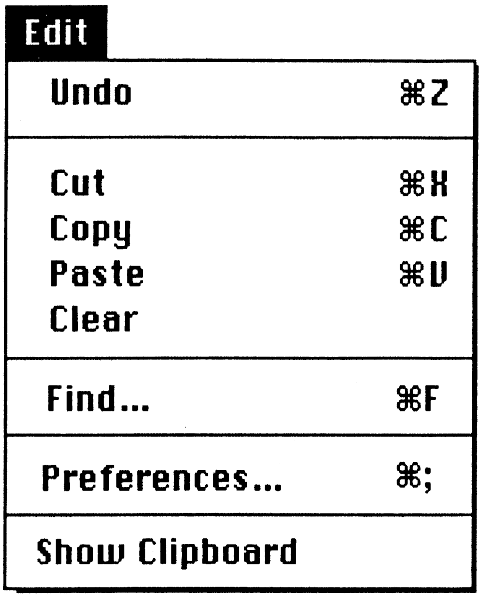
Print...

This command lets you specify various printing parameters and print a document.

Quit

This command lets you exit the program.

The Edit Menu



The **Edit** menu contains standard Macintosh editing commands, as well as application specific commands:

Undo

Reverses the effect of the previous command.

Cut

Deletes the current selection and places it on the clipboard.

Copy

Copies the current selection and places it on the clipboard.

Paste

Inserts the content of the clipboard, replacing the current selection.

Clear

Deletes the hilighted selection.

Find...

The find command displays the search dialog which is used to search the current database.

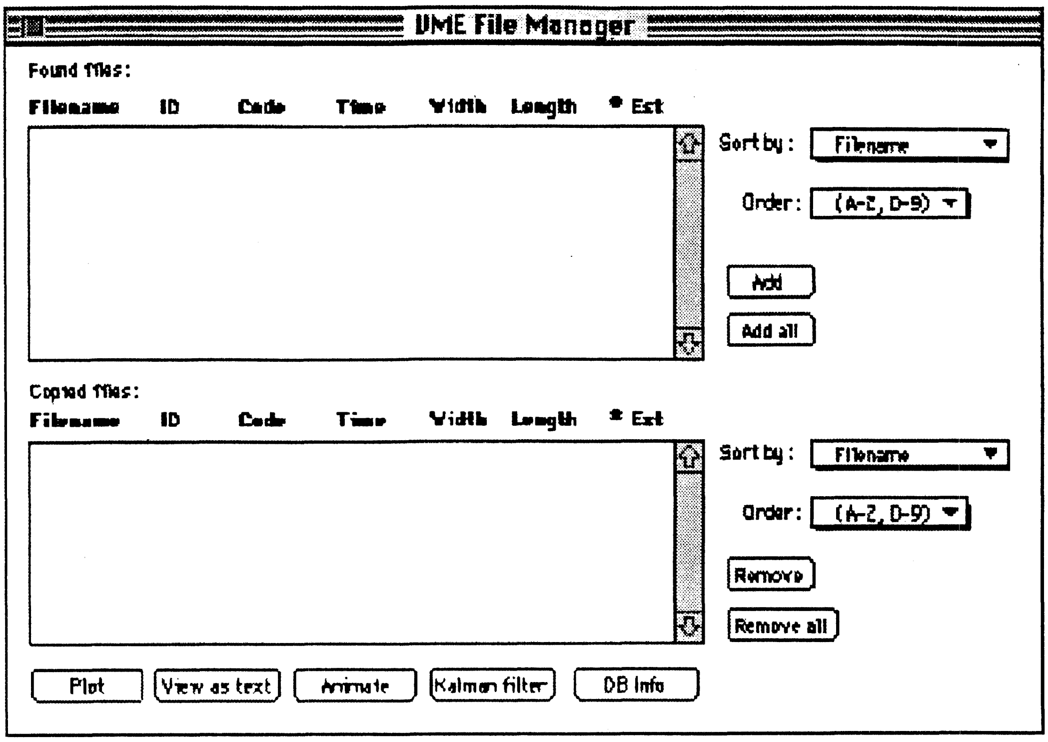


Figure 22

File Manager Window

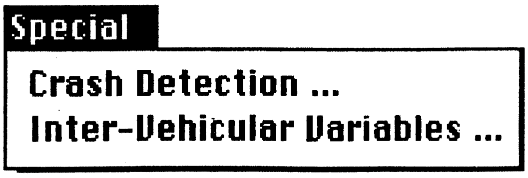
Preferences...

The preferences command opens the VME-DS preferences dialog and lets you specify application- wide settings.

Show Clipboard

The clipboard contains whatever is cut or copied from a document. It can contain text or graphics. This command displays the contents of the clipboard in a window.

The Special Menu



The **Special Calculations** menu performs specialized calculations applicable to larger groups of track files.

The **Crash Detection** special calculation module calculates the inter-vehicular gap between adjacent vehicles at each instant of time within the field of regard.

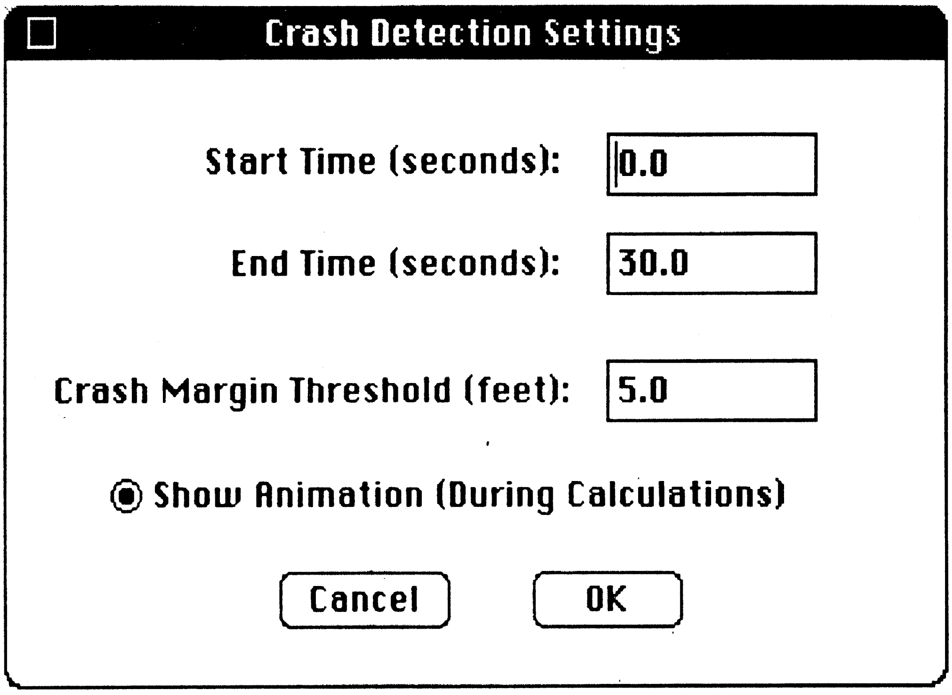


Figure 23

Crash Detection Settings

Under the **Computation of Inter-vehicular Variables** special calculation, the range and angle-of-attack between any two vehicles within the field of regard are computed and exported to a disk file. This computation occurs for each vehicle pair and for each sampling time during a time period specified by the program user.

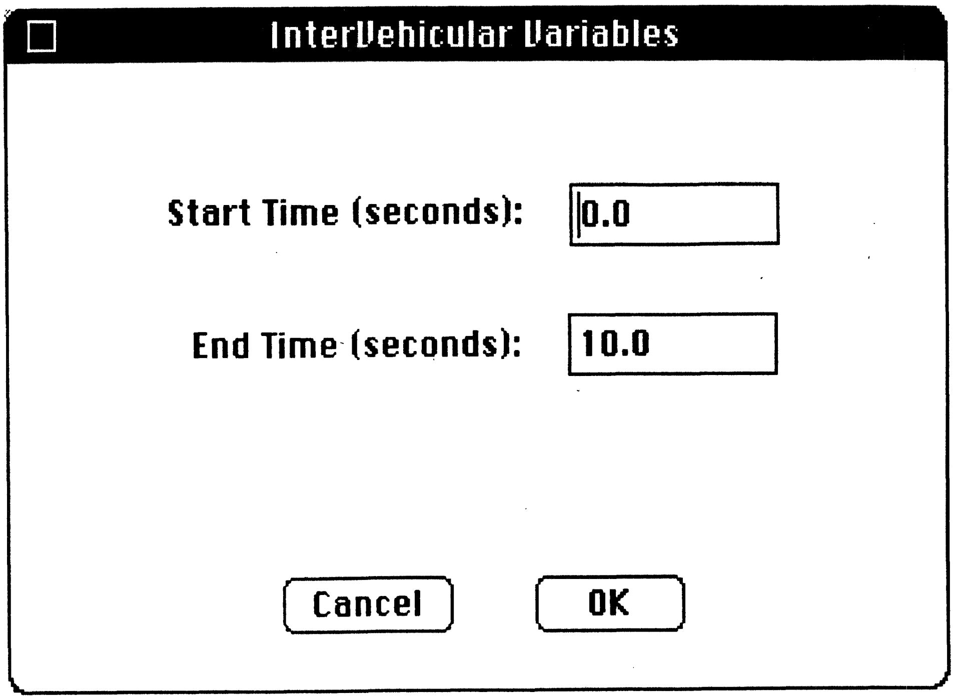
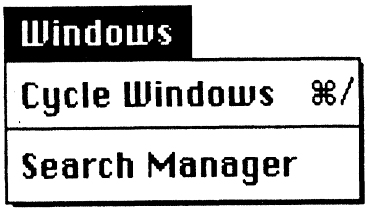


Figure 24

Inter-Vehicular Variables

The Windows Menu



The **Windows** menu lets you choose a window to display.

Cycle Windows

The **Cycle Windows** command is used to cycle, or move, to the next open window.

File Manager

The **File Manager** command is used to display the File Manager dialog.

Search Manager

The **Search Manager** command is used to display the Search Manager dialog.

VME-DS for the Macintosh

Appendixes

- A. Program Limits
- B. Track file Database Format

Appendix

A. Program Limits

- 5 primary searches and 4 sub-searches can be performed

B. Track file Database Format

A track file database is comprised of two parts - a site header record and M track files. The site header contains information specific to the site from which the data was gathered, such as the time of data collection, the total number of track file records in the database, and the site geometry This information is used by the VME-DS program in subsequent data processing operations.

Track file Database

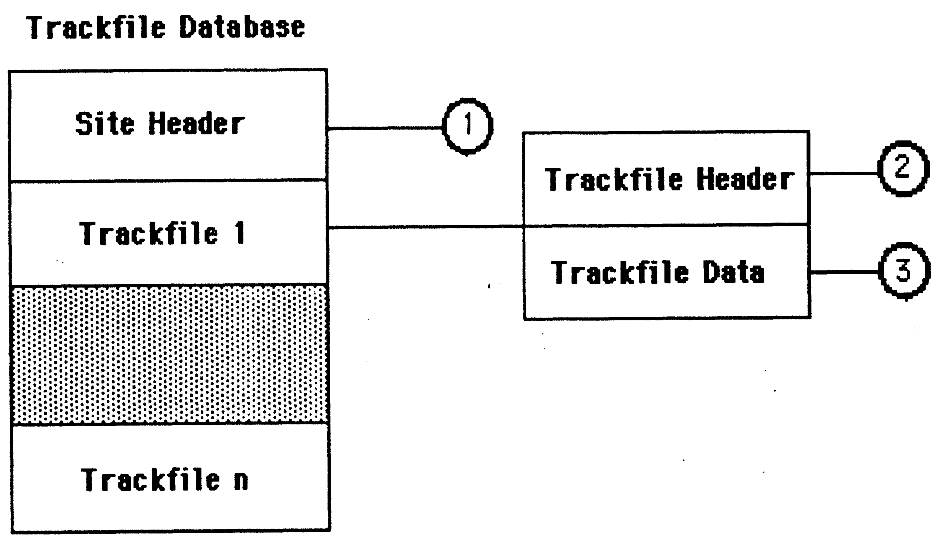


Figure 1

Track File Database Format

The database file is made up of a site header and 1..n track files. The site header (1) contains information specific to the site from which the data was gathered. The following table shows the site header format.

Table 1. Site Header Format

Item	Number of Bytes	Description
Collection ID	100 bytes	<charles>
Version ID	4 byte floating-point value	
Base Collection Time	4 byte floating-point value	
Number of track files in database	4 byte long integer value	

Each track file in the database is comprised of two sections; a header section (2) which contains information for the track file, and the data section (3), which contains the data that describes the movement of the vehicle. The following table shows the track file header and data format.

Table 2. Track Header Format

Item	Number of Bytes	Description
File Name	14 bytes	
Vehicle ID	4 byte long integer value	
Status Code	2 byte short integer value	
Encounter Time	4 byte floating-point value	
Vehicle Width	2 byte short integer value	
Vehicle Length	2 byte short integer value	
Number of Estimates	2 byte short integer value	

Table 3. Track Data Format

Item	Number of Bytes	Description
Time Relative Encounter Time	4 byte floating-point value	
X Centroid of cg	4 byte floating-point value	
Y Centroid of cg	4 byte floating-point value	
Yaw Angle of Vehicle	4 byte floating-point value	
Estimate of Standard Error	4 byte long integer value	
Sensor	4 byte long integer value	

The following listing shows a text version of a track file database.

Listing 1. Text Database File

```
000000:  3130 3020 6368 6172  7320 6F66 2053 6974   100 chars of Sit
000010:  6520 496E 666F 3A20  2020 2020 2020 2020   e Info:
000020:  2000 0000 0000 0000  0000 0000 0000 0000    ...............
000030:  0000 0000 0000 0000  0000 0000 0000 0000   ................
000040:  0000 0000 0000 0000  0000 0000 0000 0000   ................
000050:  0000 0000 0000 0000  0000 0000 0000 0000   ................
000060:  0000 0000 3F80 0000  0000 0000 0000 000B   ....?...........
000070:  3100 2020 2020 2000  0000 4080 DBEE 0000   1.       ...@.....
000080:  0001 01C9 3F00 0000  0004 000D 0064 0000   ....?........d..
000090:  0000 BEC1 779D 3E4E  BA9E BFCF 2A1E 0001   ....w.>N....*...
0000A0:  0000 3DCC CCD0 40B5  7B03 BCCF 8339 C050   ..=...@.{....9.P
0000B0:  F762 0001 0001 3E4C  CCCC 413D D2A6 BEAE   .b....>L..A=....
0000C0:  D1DE 4054 ACE9 0001  0001 3E99 999A 4191   ..@T......>...A.
0000D0:  8E6C BE79 C2F4 C070  DF22 0001 0001 3ECC   .l.y...p."....>.
0000E0:  CCCC 41C0 9DF9 3D89  40AC C08F 183E 0001   ..A...=.@....>..
0000F0:  0001 3F00 0000 41F1  DA9B BEAE 6510 C035   ..?...A.....e..5
000100:  E9AC 0001 0001 3F19  999A 4210 9905 3B5C   ......?...B...;\
```

```
000110:  281F BF43 1686 0001  0001 3F33 3334 4229   (..C......?334B)
000120:  3763 BDBF 11E5 C060  B781 0001 0001 3F4C   7c.....`......?L
000130:  CCCC 423F D3A7 3E1E  32A3 400B C6D8 0001   ..B?..>.2.@.....
000140:  0001 3F66 6666 4257  EE15 BE7E BA98 3F8E   ..?fffBW...~..?.
000150:  049C 0001 0001 3F80  0000 4270 9BC8 BEA0   ......?...Bp....
000160:  2EF4 BFB5 76EB 0001  0001 3F8C CCCD 4284   ....v.....?...B.
000170:  B099 BE31 232F 3FB6  3CEC 0001 0001 3F99   ...1#/?.<.....?.
000180:  999A 428F 2B54 BE6A  DC09 C00E 3CDC 0001   ..B.+T.j....<...
000190:  0001 3FA6 6666 429B  C759 3C43 6CEE 407D   ..?.ffB..Y<Cl.@}
0001A0:  0B48 0001 0001 3FB3  3333 42A7 275B BED8   .H....?.33B.'[..
0001B0:  1FDF 3FD1 3C67 0001  0001 3FC0 0000 42B4   ..?.<g....?...B.
0001C0:  5F65 3D8A 3C38 4037  890C 0001 0001 3FCC   _e=.<8@7......?.
0001D0:  CCCC 42BF F457 3EC4  2C84 C054 F3EF 0001   ..B..W>.,..T....
0001E0:  0001 3FD9 999A 42CC  B788 3E8C 78CE C02B   ..?...B...>.x..+
0001F0:  562D 0001 0001 3FE6  6666 42D8 B839 BE19   V-....?.ffB..9..
000200:  4DD2 4064 C4DC 0001  0001 3FF3 3334 42E3   M.@d......?.34B.
000210:  6487 BE14 88DA 4054  62DC 0001 0001 4000   d.....@Tb.....@.
000220:  0000 42EF C0E5 3E39  E368 C04A E834 0001   ..B...>9.h.J.4..
000230:  0001 4006 6666 42FC  A610 3ED9 FD0E 3E1E   ..@.ffB...>...>.
000240:  5248 0001 0001 400C  CCCD 4304 026D 3F49   RH....@...C..m?I
000250:  E616 4032 5E7A 0001  0001 4013 3333 4309   ..@2^z....@.33C.
000260:  CA8B 3F48 0FD7 403C  3864 0001 0001 4019   ..?H..@<8d....@.
000270:  999A 430F 9DD2 3F91  F168 40AC 2736 0001   ..C...?..h@.'6..
000280:  0001 4020 0000 4315  D7A6 3F97 C7FB 40A5   ..@ ..C...?...@.
000290:  BA46 0001 0001 4026  6666 431B F9A9 3FA6   .F....@&ffC...?.
0002A0:  FFA9 BEE4 9DD8 0001  0001 402C CCCD 4322   ..........@,..C"
0002B0:  2774 3FE2 E107 4059  7C9C 0001 0001 4033   't?...@Y|.....@3
0002C0:  3333 4328 0F84 4008  D1FE 4062 F03C 0001   33C(..@...@b.<..
0002D0:  0001 4039 999A 432D  A460 403D 0DB9 3FB8   ..@9..C-.`@=..?.
0002E0:  A52C 0001 0001 4040  0000 4334 15DE 4073   .,....@@..C4..@s
0002F0:  BA25 40D0 05E4 0001  0001 4046 6666 4339   .%@.......@FffC9
```

Catalog File

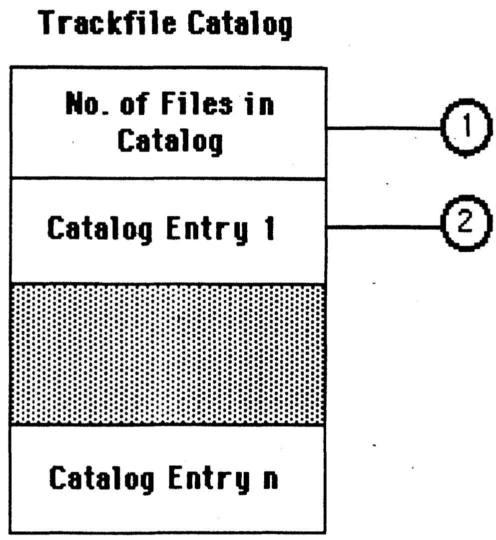


Figure 2

Track File Catalog Format

The catalog file is made up of the number of files in the catalog (1) and 1..n catalog entries. The following table outlines the catalog file format.

Table 4. Catalog File Format

Item	Number of Bytes	Description
Number of Total Files in Database	4 byte long integer value	
File Name	14 bytes	
Vehicle ID	4 byte long integer value	
Status Code	2 byte short integer value	
Encounter Time	4 byte floating-point value	
Vehicle Width	2 byte short integer value	
Vehicle Length	2 byte short integer value	
Number of Estimates	2 byte short integer value	

Mapper Offset to Header	4 byte long integer value	A mapper offset is an index into the data sections of the database and are used by the database search algorithm to find information quickly.

Listing 2. Text Catalog File

```
000000:  0000 000B 3100 2020  2020 2000 0000 4080   ....1.      ...@.
000010:  DBEE 0000 0001 01C9  3F00 0000 0004 000A   ........?.......
000020:  0064 0000 0070 3200  2020 2020 2000 0000   .d...p2.      ...
000030:  4080 DBEE 0000 0002  01CA 4027 AE14 0004   @.........@'....
000040:  000E 0064 0000 085E  3300 2020 2020 2000   ...d...^3.      .
000050:  0000 4080 DBEE 0000  0003 01CB 4087 AE14   ..@.........@...
000060:  0005 000F 0064 0000  104C 3400 2020 2020   .....d...L4.
000070:  2000 0000 4080 DBEE  0000 0004 01CC 408B    ...@.........@.
000080:  851F 0005 0010 00C8  0000 183A 3500 2020   ...........:5.
000090:  2020 2000 0000 4080  DBEE 0000 0005 01CD      ...@.........
0000A0:  40DF 5C29 0005 0011  005A 0000 27F8 3600   @.\).....Z..'.6.
0000B0:  2020 2020 2000 0000  4080 DBEE 0000 0006        ...@.......
0000C0:  01CE 4109 999A 0006  0012 0064 0000 2F1E   ..A........d../.
0000D0:  3700 2020 2020 2000  0000 4080 DBEE 0000   7.      ...@.....
0000E0:  0007 01CF 4123 851F  0006 0013 00C8 0000   ....A#..........
0000F0:  370C 3800 2020 2020  2000 0000 4080 DBEE   7.8.      ...@...
000100:  0000 0008 01D0 4155  70A4 0006 0014 0050   ......AUp......P
000110:  0000 46CA 3900 2020  2020 2000 0000 4080   ..F.9.      ...@.
000120:  DBEE 0000 0009 01D1  416F 5C29 0007 0015   ........Ao\)....
000130:  0064 0000 4D28 3130  0020 2020 2000 0000   .d..M(10.      ...
000140:  4080 DBEE 0000 000A  01D2 4184 A3D7 0007   @.........A.....
000150:  0016 0096 0000 5516  3131 0020 2020 2000   ......U.11.     .
```

Index

VME Pre-Processor

User's Guide

Version 1.0

VME Pre-Processor for Macintosh™ User's Guide

by Kevin O'Malley

VME Pre-Processor is provided "as-is", without warranty. We assume no responsibility for any errors, or for damages resulting from the use of the information contained herein.

VME Pre-Processor

User's Guide

Contents

VME Pre-Processor

Getting Started

- Introduction
- What you should know
- System Requirements
- Installation
- Technical Support

Getting Started

Introduction

VME Pre-Processor is a potentially dangerous program when used incorrectly. It is intended to be used only for reading raw track file databases from a DAT (Digital Audio Tape). Do not use the prograr to read data from your hard drive.

What You Should Know

This manual assumes that you know, or are learning, how to use a Macintosh Computer with System 7 or greater. If you encounter any problems using your Macintosh, please see your Macintosh User's Guide.

System Requirements

VME Pre-Processor runs on Macintosh computers equipped with System 7 or greater. Table 1 summarizes the requirements.

Table 1. System requirements for VME Pre-Processor

Feature	Status	Requirement
CPU	Required Recommended	Macintosh with 68030 Macintosh with 68040
Co-processor	Recommended	Math co-processor
Operating System	Required	System 7 or greater
RAM Memory	Required	4 MB or more
Hard Disk Space	Required	250 KB free or more
DAT Drive	Required	
Media	Required	3.5" floppy drive
Monitor	Required	
Printer	Recommended	

Installation

To install VME Pre-Processor from the VME Pre-Processor distribution disk, drag the folder `VME Pre-Processor` to your hard disk.

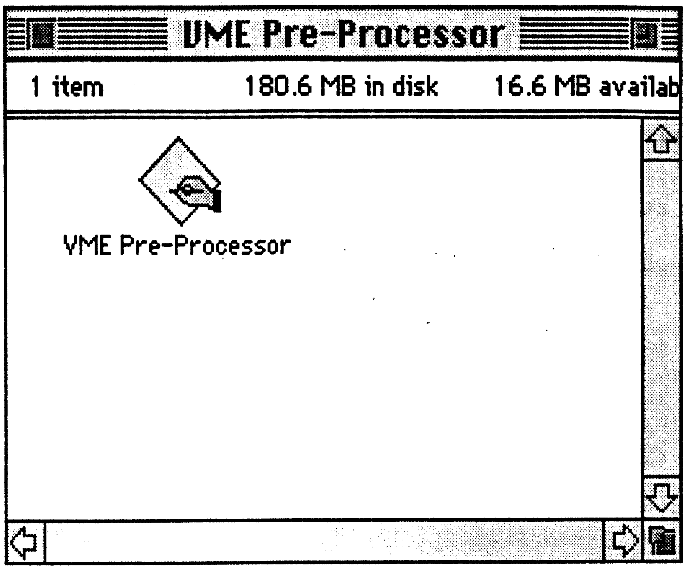


Figure 1

VME-Pre-Processor Folder Contents

Technical Support

Help is available on-line within the VME Pre-Processor program. This provides help with the most common problems. If further assistance is necessary, contact us via e-mail, providing the following information:

- Version number and date of VME Pre-Processor (found in the About Box)
- A description of the problem, including what occurred and any error messages that were displayed
- Information on the system that was being used when the problem occurred

Internet: omalley@umich.edu.

VME Pre-Processor

Tutorial

- Selecting a SCSI device
- Sending commands to the selected SCSI device
- Reading data from a SCSI device

Tutorial

Use this tutorial to familiarize yourself with the features and abilities of VME Pre-Processor. You will learn how to select a SCSI (Small Computer Systems Interface) device, send SCSI commands to the selected device and read data from that device.

Selecting a SCSI Device

To begin using VME Pre-Processor, open the folder that contains the VME Pre-Processor program (VME Pre-Processor) and double click on the VME Pre-Processor icon.

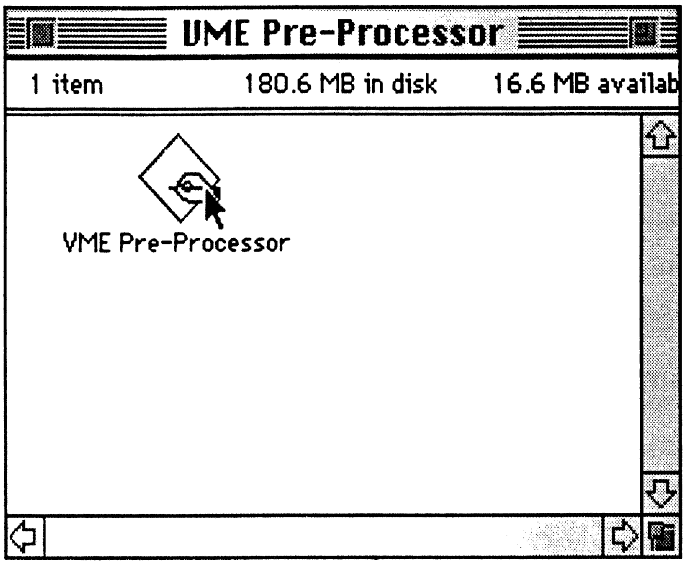


Figure 2

Launching the VME-Pre-Processor program

VME Pre-Processor displays an opening log window that lists the current SCSI devices on the SCSI chain and a message that instructs you to select the target device.

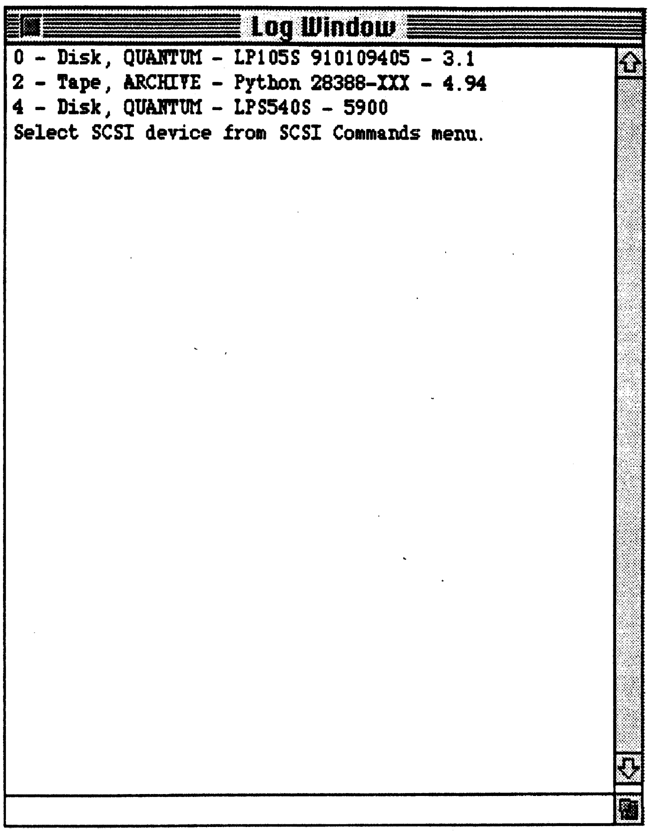


Figure 3

Initial Log Window

Select the ID or your DAT device from the **SCSI Commands:Set SCSI ID**. The selected device ID number will be displayed in the log window.

Sending Commands to the SCSI Device

Commands can be sent to the selected SCSI device using the **SCSI Commands** menu. For example, to get a list of the current devices on the SCSI chain, select the **Device List** command. The currently active devices will be written to the log window.

Reading Data from a SCSI device

For this tutorial we will read 500 blocks from the DAT. Select **Read blocks from DAT...** from the **DAT Commands** menu. When the dialog appears type 1 into the read field and 500 into the to field.

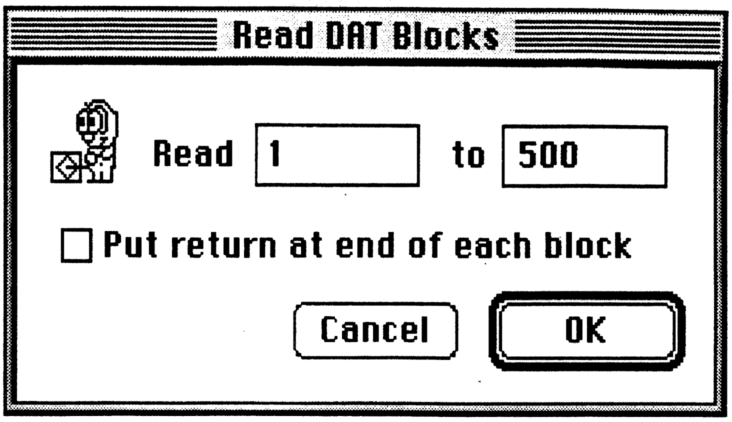


Figure 4

Read DAT Blocks Dialog

Click the **OK** button. The log window displays status information while the device is read.

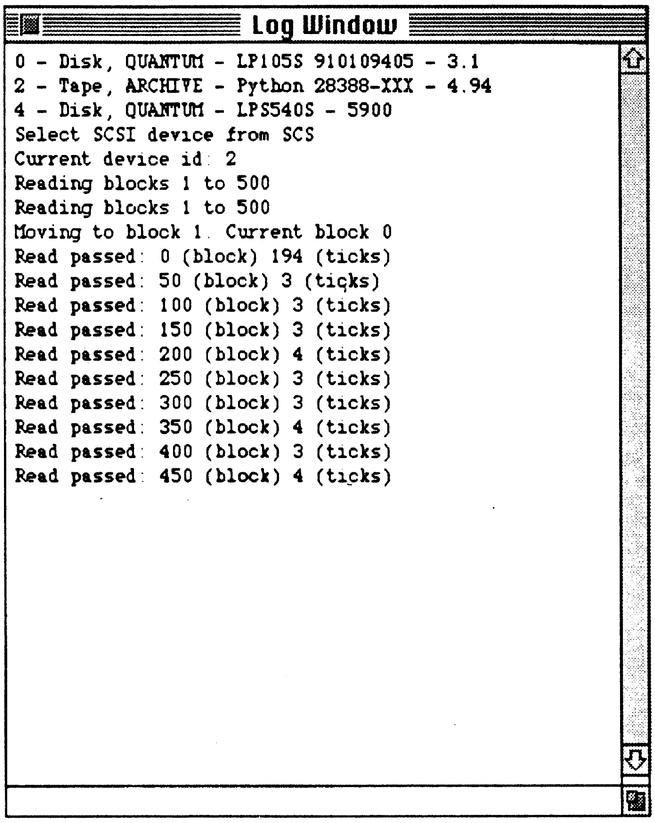


Figure 5

Log Window Displaying Status Information

VME Pre-Processor

Menus

- File menu
- Edit menu
- Special menu
- Windows menu

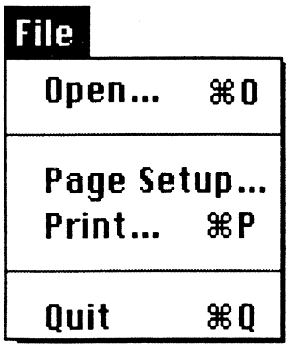
VME Pre-Processor Menus

The Apple Menu

About VME Pre-Processor...

Displays a dialog box that tells what version of the program is being used

The File Menu



The file menu is used to perform application filing options such as opening and closing files. This menu has the command which allows you to quit the program.

Open...

Displays a dialog box that lets you choose a text file to open

Page Setup...

Specifies printing parameters which control the printed document

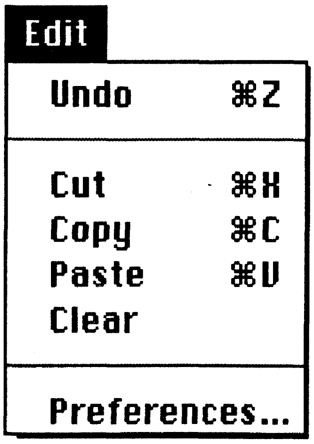
Print...

Specifies various printing parameters and print a document

Quit

Exits the program

The Edit Menu



The **Edit** menu contains standard Macintosh editing commands:

Undo

Reverses the effect of the previous command

Cut

Deletes the current selection and places it on the clipboard

Copy

Copies the current selection and places it on the clipboard

Paste

Inserts the content of the clipboard, replacing the current selection

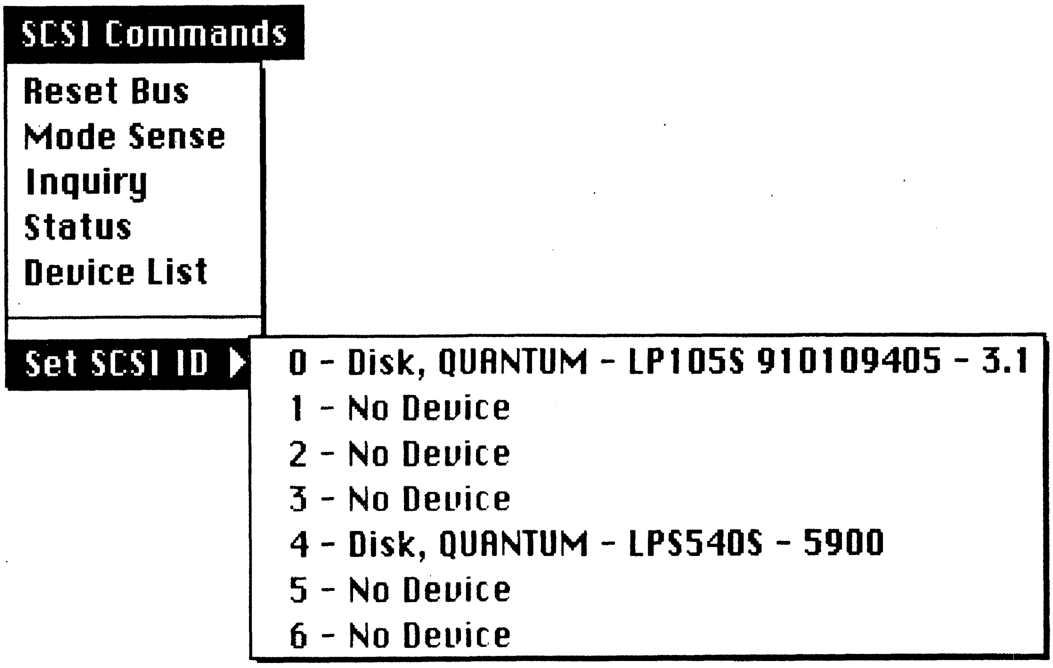
Clear

Deletes the hilighted selection

Preferences...

Opens the **VME Pre-Processor** preferences dialog and allows you to specify application-wide settings

The SCSI Commands Menu



The **SCSI Commands** menu contains commands allowing you to send SCSI commands to the DAT drive.

Reset Bus

Immediately clears all SCSI devices from the bus

Mode Sense

Performs the mode sense command

Inquiry

Returns information about the specified SCSI device, including a code for the device type, the manufacturer's name, and the firmware version

Status

Requests that status information be sent from the target to the initiator

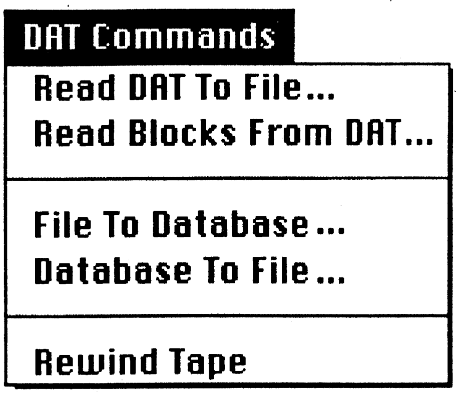
Device List

Displays a list of all SCSI devices on the SCSI chain in the **Log Window**

et SCSI ID

Sets the target SCSI device

The DAT Commands Menu



The **DAT Commands** menu contains commands allowing DAT specific SCSI commands to be sent to the DAT drive.

Read DAT To File...

Reads the entire contents of the DAT to a file

Read Blocks from DAT...

Reads a range of blocks from the DAT to a file

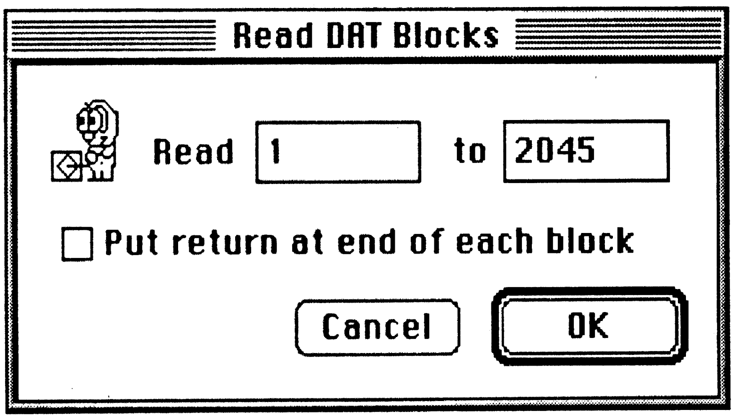


Figure 6

Read DAT Blocks Dialog

File to Database...

Converts a text file into a Trackfile database

Database to File...

Converts a Trackfile database into a text file

The Windows Menu

The **Windows** menu lets you choose a window to display.

Log Window

Activates the log window which is used to display the results of SCSI and DAT commands

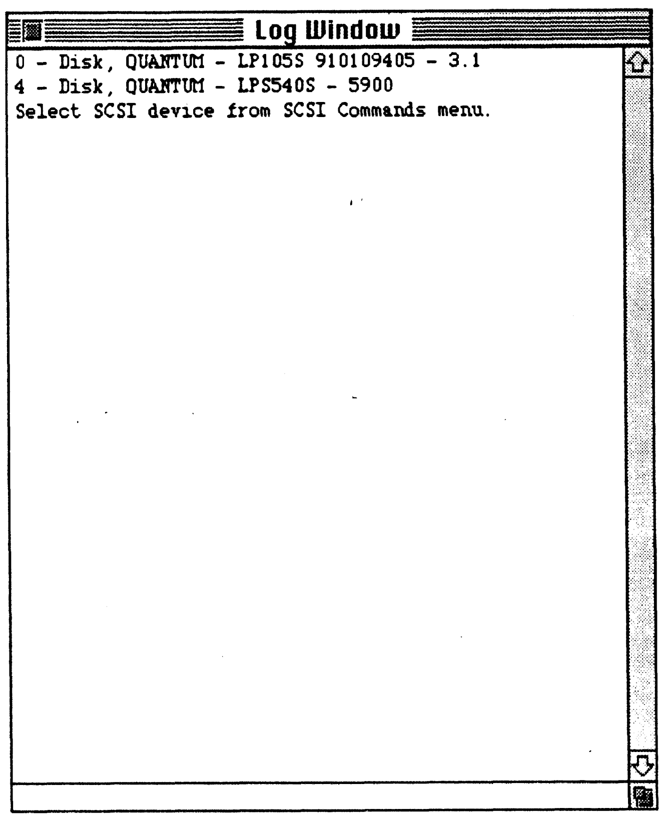


Figure 6

Log Window

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Appendix D

Approvals and Certifications:

1) City of Ann Arbor, Michigan

2) Federal Aviation Administration

3) Food and Drug Administration, Center for Devices and Radiological Health

City of Ann Arbor, Michigan:

1) Petition for Minor Modifications

2) Building Permit

3) Zoning Board of Appeals Variances

ERIM P.O. Box 134001
Ann Arbor, MI 48113-4001
313-994-1200

11 April, 1994

Ms. Karen Popek Hart, Director
Planning Department
City of Ann Arbor
100 North Fifth Avenue
Ann Arbor, MI 48104-1406

Re: Petition for Site Plan for Minor Modifications
Vehicle Motion Environment - Measurement System Project (VME-MS)

Dear Ms. Hart:

Based on my discussions with you and with Mr. Jack Donaldson, City Building Department Director, we are submitting the attached Application, 15 folded Site Plan prints (22"x34"), 1 original Site Plan reduction (8-1/2"x11"), and a Site Plan Fee check payable to the City of Ann Arbor in the amount of $825 for above project. This project is a joint venture between ERIM, University of Michigan Transportation Research Institute (UMTRI) and the Michigan Department of Transportation (MDOT) to provide measurement and monitoring research of normal traffic flows along Plymouth Road at ERIM as part of a federally funded NHTSA grant. We are also providing the attached information explaining details of the project.

Key points to note:
*Project consists of three trailer-conveyed, telescoping metal tower units (100' max. ht.) with engineering and installation by qualified manufacturer (ALUMA Tower Co.)
*All three trailers, associated structural guys, and containment fencing will be sited to be inside the existing ERIM property line.
*The only items outside ERIM property will be 6 to 10 measurement "tape switches" in the roadway adjoining the towers installation. These switches will be installed according to standard traffic-count engineering practice. Wires connecting back to the trailers will be installed underground below existing sidewalk along Plymouth Road.
*Units will be guyed to comply with local Code standards for structures of this type as approved by the City Building Department.
*Each unit will have required electrical grounding for the duration of the installation.
*A security fence will be installed around the entire perimeter of the installation in compliance with applicable City Code requirements.
*24-hour security guard will be provided.
*Estimated project duration approximately six (6) weeks.
*Estimated start date of installation approximately 10 June, 1994. (This date may vary depending on sponsor variables.)

Ms. Karen Popek Hart, Director
Planning Department
City of Ann Arbor

We also understand from our discussions that approval will be required from the City Zoning Board of Appeals for variance from the required front setback and the maximum height restrictions on subject property. We are applying separately for this request by 20 April, 1994 for the ZBA Hearing scheduled for 18 May, 1994. You have informed me that information from the Planning Commission meeting of 17 May, 1994 regarding this project will be made available for the ZBA Hearing. We appreciate your assistance in this unique and important project.

Please feel free to contact me (994-1200, Ext. 2812) or Mr. Kent Gilbert, ERIM Project Engineer (Ext. 2320) should you require further information.

Respectfully Submitted,

Robert Black/Facility Planning

cc:
K. Gilbert
R. Nalepka
N. Sears
R. Smith

PETITION APPLICATION FORM

Ann Arbor City Planning Department
100 North Fifth Avenue
P.O. Box 8647
Ann Arbor, Michigan 48107
(313)994-2800
In Effect December 20, 1993

Project Name Vehicle Motion Environment-Measurement System (VME-MS)

Project Type Temporary Safety Traffic Research

Property Address and Location 3300 Plymouth Rd. Ann Arbor 48107

Property Owner ERIM (Environmental Research Institute of Michigan)

Address P.O. Box 134001

Ann Arbor, Michigan 48113-4001 *Telephone* (313) 994-1200

Petitioner (if other than owner) SAME

Interest in Property

Address

Telephone ( )

Petitioner's Agent Office of Facility Planning

Contact Person Robert Black/Architect

Address P.O. Box 134001

Ann Arbor, Michigan *Telephone* (313) 994-1200 Ext. 2812

OFFICE USE ONLY	
Total Land Area	
File Number	
Filing Date	
Public Hearing Date	
Total Fee Paid (See Reverse for Fee Schedule)	

ACCEPTED FOR SUBMISSION BY ______________________ DATE ____________

GENERAL INFORMATION

a. Project name:
VEHICLE MOTION ENVIRONMENT - MEASUREMENT SYSTEM (VME-MS)

b. Petitioner:
Environmental Research Institute of Michigan
P.O. Box 134001
Ann Arbor, MI 48113-4001
Attention: Mr. Robert Black/Architect
Office of Facility Planning
Phone: 994-1200 X2612

c. See Site Plan for North indicator

d. The existing (and proposed) zoning for the site is ORL, Office/Research/Limited Industrial District.

e. The proposed project has no "floor area"

f. The approximate proposed height of the structures is 100 feet.

g. Statement of Ownership in property:
The Environmental Research Institute of Michigan (ERIM) is the owner of the property

h. See Area Plan for applicant's entire holding and interest in land contiguous to the proposed installation.

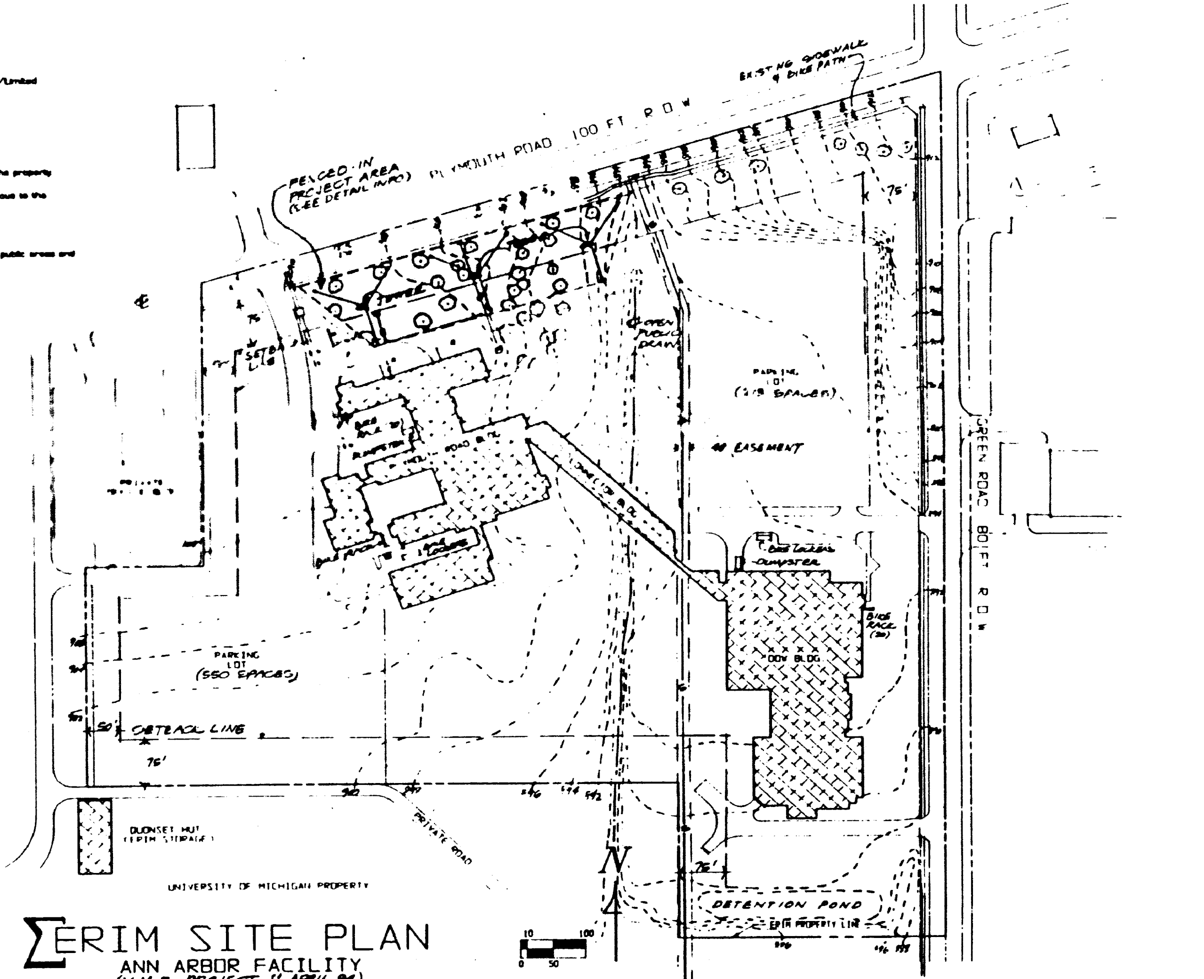
i. See Area Plan for "Vicinity Map"

k. See Site Plan for location and identification of public drain and all other public areas and municipal corporation lines within or adjacent to the site

l. Legal description shown on the Site Plan

LEGAL DESCRIPTION

[illegible]



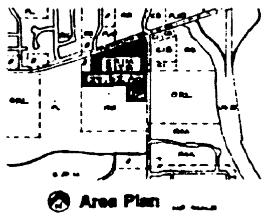
ERIM SITE PLAN

ANN ARBOR FACILITY

(V.A.I.E. PROJECT 11 APRIL 94)

CITY OF ANN ARBOR
ZONING DISTRICT KEY

R1C SINGLE FAMILY DWELLING
R4A MULTIPLE FAMILY DWELLING
R5 MOTEL/HOTEL
PUD PLANNED UNIT DEVELOPMENT
O OFFICE
PL PUBLIC LAND
RE RESEARCH
C1 LOCAL BUSINESS
C1B COMMUNITY CONVENIENCE CENTER
CB PLANNED CENTER
ORL OFFICE/RESEARCH/LIMITED INDUSTRIAL



Area Plan

REVISIONS

DEVELOPMENT PROGRAM

a. The proposed project is a joint venture between ERIM, the University of Michigan Transportation Research Institute (UMTRI) and the Michigan Department of Transportation (MDOT) to provide measurement and monitoring research of normal traffic flows along Plymouth Road at ERIM as part of a federally funded National Highway Traffic Safety Administration (NHTSA) grant. This research will aid in future development of automotive active safety technologies for Intelligent Vehicle Highway System (IVHS) applications.

b. The project consists of three, trailer-conveyed, telescoping tower units (100' height) with 3-D imaging laser radars mounted on top of each tower.
Containment fencing will encompass all three trailer/towers and associated guys to prohibit uncontrolled access and to protect public safety. 24-hour security guard will be provided.

c. Scheduled start date 10 June, 1994 with project duration estimated at approximately six (6) weeks.

d. The probable installation cost for the project is $10,000

COMMUNITY ANALYSIS

a. There is no impact to public schools from the proposed project.

b. The proposed project is temporary in nature and will not permanently affect the site or neighboring uses. Safety is being carefully addressed and managed for the proposed project - in the structural integrity of the towers, eye-safe laser operation and control of public access to the system. (See attached information for more details)

d. There is no known impact on the proposed project by adjacent uses

e. There will be no impact to the natural features of the site. any disturbance of front lawn will be restored to pre-project conditions

f. There is no impact on historic sites from the proposed project.

SITE ANALYSIS

a. The existing land use is research oriented activities

b. An inventory of site conditions, including topography and site vegetation is shown on the Site Plan.

c. Existing structures are shown on the Site Plan. reference also the attached Site Survey prepared by Atwell-Hicks, Inc./Civil Engineers, Surveyors, Planners showing existing property lines, building locations and legal conditions at the subject property.

d. The existing vehicular, pedestrian and bicycle ways are shown on the Site Plan.

e. Existing utilities and proposed electrical connection to project is shown on the Site Plan.

f. The existing drainage pattern is shown on the Site Plan and will not be affected by the proposed project.

SCHEMATIC DESIGN

a. Comparison Chart

	Zoning District	Max. Useable Floor Area (% Lot Area)	Required Setback Line Minimum Dimension (ft) Front	Side Least/Total		Rear	Maximum Height In Feet	In Stories	Minimum Lot Size Area (sq ft)	Width (ft)
CITY CODE	ORL	40%	75	50	100	75	50	4	40,000	150
PROPOSED	ORL	50%*	61**	500	700	880	100**	N/A	1,877,160	1,160

* The proposed temporary project adds 0% to the existing total floor area

** A variance from required front setback and maximum allowable height is being petitioned separately before the Ann Arbor Zoning Board of Appeals, 10 May, 1994

b. The existing topography at two foot intervals and the existing drainage are shown on the Site Plan. There are no "proposed" contours as part of this project.

c. The orientation and general location of the proposed temporary improvements are shown on the Site Plan and the attached supporting information.

d. Vertical elevation of the proposed installation is shown in the attached supporting information.

e. Proposed circulation patterns on the site are shown on the Site Plan.

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE
DIM ENDING .00 ± .015
DIM ENDING .000 ± .005
ANGULAR ± 0°-30'

DAVIS 7/?

ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN

SITE PLAN for MINOR MODIFICATIONS V.M.E. PROJECT (4·11·94)

UMTRI The University of Michigan
Transportation Research Institute
2901 Baxter Road, Ann Arbor, Michigan 48109-2150

February 7, 1994

Dr. Kunwar Rajendra
Engineer of Transportation Systems
Michigan Dept. of Transportation
425 West Ottawa
Post Office Box 30050
Lansing, MI 48909

Dear Kunwar:

This letter is to request MDOT's assistance in preparation for field testing of a roadside instrument system along a Michigan trunkline roadway in Ann Arbor. As you may recall, the Department partnered with UMTRI and ERIM when we proposed a $1.4 million (federal funds) project to NHTSA for building and testing a new system called the Vehicle Motion Environment (VME). This system employs a sophisticated laser-imaging technology to measure vehicular motions along short sections of roadway. The data produced by this system will be used to support the development and evaluation of IVHS technologies for helping drivers in collision avoidance. We began the project in the fall of 1992 and are now approaching the time when the system is to be tested.

ERIM is building the measurement apparatus in the form of three portable towers that are to be installed along the roadside for the measurement of traffic over a few-weeks period. The attached materials describe the system that is currently under construction and outlines the nominal plan for testing. We wish to request MDOT's assistance and advice in arranging for the initial trial of this equipment along Plymouth Road (originally the M-14 trunkline highway) in northeast Ann Arbor. We are assuming that the Department (and maybe the City of Ann Arbor?) should be involved in approving the safe placement of equipment at this site.

The ERIM project leader is Kent Gilbert. I would ask that you review the attached materials and contact Kent with advice on how we should proceed. We are certainly grateful for MDOT's participation with us in this significant portion of the IVHS initiative. Thanks for your help.

Very Truly Yours,

Bob

Bob Ervin
VME Project Director

OVERVIEW OF THE VME MEASUREMENT SYSTEM (VME-MS)

In 1989, a concept for measurement and analysis of the so-called "Vehicle Motion Environment" (VME) was formed by Robert D. Ervin of the University of Michigan Transportation Research Institute (UMTRI). This vehicle motion environment consists of complex vehicle motion and inter-vehicular dynamics. Subsequently, in 1991, UMTRI and ERIM jointly published a report entitled "The Feasibility of Quantitatively Characterizing the Vehicle Motion Environment"[1]. Then, in June of 1992, UMTRI and ERIM submitted a proposal to the National Highway Traffic Safety Administration (NHTSA) to employ multiple 3-D imaging laser radars for the purpose of quantitatively characterizing the VME via an archive of pre-accident information[2]. This was in direct response to a recognized need for a fundamental understanding of the vehicle motion environment, to aid in the future development of automotive active safety technologies for Intelligent Vehicle Highway System (IVHS) applications.

In September 1992, UMTRI and ERIM entered into a cooperative agreement with the NHTSA to develop, build, and test a fully-functional measurement system (VME-MS) and data processing system (VME-DS). ERIM's role is to specify, develop, procure, and deploy the VME-MS, the output of which will be track files of each vehicle's centroid and yaw throughout the system's field-of-view. UMTRI is responsible for the development of the VME-DS which will post-process the track files to ascertain finely detailed vehicle dynamics.

Future automotive active safety feature design requires detailed knowledge of inter-vehicular trajectory dynamics. This fundamental premise precipitated the desire to quantitatively characterize the VME. Unfortunately, the VME is not a static, easily-measured object. By its very nature, it is complex and dynamic and can therefore only be characterized in a statistical sense. The vast diversity of road conditions, weather patterns,

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[1]Ervin, R.D., MacAdam, C.C., Gilbert, R.K., and Tchoryk, P., "Quantitati Characterization of the Vehicle Motion Environment (VME)," SAE Paper No. 912854, *Proceedings of the Vehicle Navigation and Information Systems Conference*, Dearborn, MI, 199

[2]Ervin, R.D., MacAdam, C.C., Gilbert, R.K., "A Measurement and Processing System for the Vehicle Motion Environment (VME)," *Proceedings of the IVHS America 1993 Ann Meeting*, Washingtom, D.C., 1993.

and driver behavior dictates several demanding operational requirements for the VME-MS. First, this vast diversity demands in situ generation of vehicle centroid and heading trajectories. It is not sufficient to collect some data on a test track, under ideal conditions, using professional drivers. Rather, it is necessary to characterize real drivers in day-to-day traffic scenarios. Second, the VME-MS is required to operate around the clock, under all weather conditions in order to obtain statistically representative and comprehensive treatment of all possible scenarios. Third, operational requirements dictate that the VME-MS perform real-time track generation and archival. The tremendous data demands (i.e., wide-area coverage, high measurement rate, and long time duration) require processing the measured scene in real-time and reducing it to a few critical parameters, which must subsequently be archived for post-processing. Finally, the VME-MS must be deployable in diverse roadway configurations. The simplest deployment scenario, depicted in Figure 1, consists of three Sensor Stations that view a contiguous, 600 linear feet of roadway. This is the proposed configuration for the initial demonstration of the VME-MS; however, the VME-MS has been designed to accommodate intersections, entrance/exit ramps and other more complex configurations. Furthermore, the system is expandable to incorporate additional Sensor Stations. The VME-MS creates a seamless track file for each vehicle that traverses the field-of-view (FOV) of the entire collection of Sensor Stations. The track file data is stored on magnetic tape that will be collected on a daily basis and transferred to the VME-DS for processing.

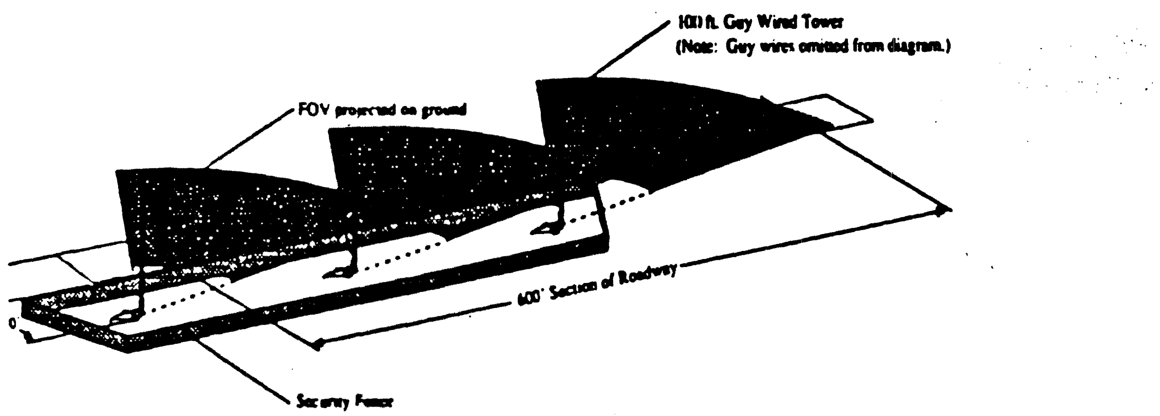


Figure 1: Typical perspective view for the VME-MS deployed at the roadside.

PROPOSED SITE PLAN

For the initial demonstration of the VME-MS, ERIM proposes to deploy three Sensor Stations on the South side of Plymouth Road between the Green Road-Plymouth Road Intersection and the entrance to ERIM's Plymouth Road Building. A preliminary layout of the three Sensor Stations is shown in Figure 2. The final location of the VME-MS, both in terms of setback from Plymouth Road and distance from the intersection, are under study. For locating the VME-MS, the area enclosed by the fence should be considered fixed in terms of its overall dimensions. The precautionary measures that have been designed into the system to ensure the public's safety are described in the following section.

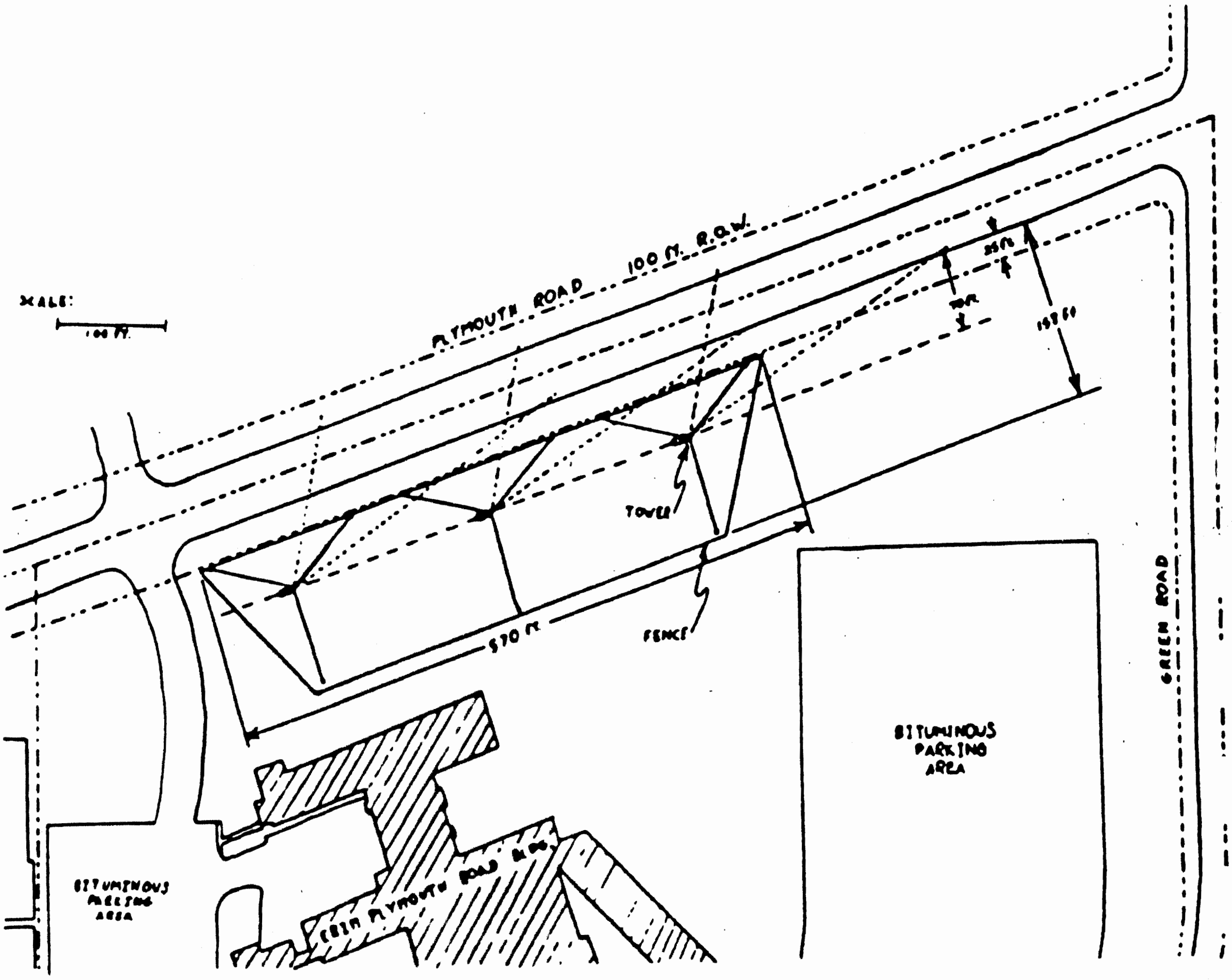


Figure 2: Preliminary Plymouth Road Layout for the VME-MS.

SAFETY

Three aspects of the VME-MS design are addressed in the following paragraphs: its mechanical integrity; eye-safe laser operation; and public access to the system.

Mechanical Design: The demonstration VME-MS will consist of three measurement stations, or Sensor Stations. Each Sensor Station will include a weather-proof enclosure containing all control, processing, and data recording electronics, and a measurement platform supporting a laser radar camera and video camera. The platform used for mounting the VME sensors is a trailer-mounted, retractable tower manufactured by Aluma Tower. The tower extends in four sections to a maximum height of 100 ft. Each section is guyed to the ground using 3 guy wires, for a total of 12 guy wires per tower. The 100-ft guyed configuration is designed for 100 mph winds with an antenna load of 11 square feet. The VME sensor assembly produces a maximum antenna load of 2.75 square feet, therefore the towers will be well within the manufacturer's design guidelines for stable operation in winds up to 100 mph. In the event that severe weather is forecast, the towers will be retracted. Tower extension and retraction requires approximately 1 hour. Therefore, the Sensor Stations are safe, from a weather perspective, regardless of weather conditions.

Eye-Safe Laser Operation: The principal instrument for collecting data in the VME application is the tower mounted Lasar Datacamera manufactured by Perceptron. This instrument uses a scanning infrared laser radar to produce a three dimensional image of the scene. Proper and conservative precautions have been taken to insure that the laser radiation emitted from the sensor will be safe for operation in a public setting. The laser operates at an invisible infrared wavelength, therefore it will not be a distraction to drivers. The remaining precaution that has to be considered is with regards to laser eye safety. Federal eye-safety standards established by ANSI and CDRH, the Center for Devices and Radiological Health, require that the laser sensor be safe even when directly viewed by an observer using binoculars with 50 mm apertures. For the VME-MS, this distance is 50 feet from the laser sensor (i.e., The laser sensor is eye-safe whenever it is viewed at a distance greater than 50 feet.) which will be mounted on the top of a 100 foot tower. With the addition of a security fence, the closest anyone on the ground can approach the laser sensor is slightly greater than 100 feet, well into the eye-safe range. (This corresponds to an individual standing at the fence, at a point closest to the laser sensor, and looking straight at the sensor. The perimeter of the fence, however, <u>is not</u> within the laser sensor's FOV, and thus the minimum range from the sensor at which vehicles are scanned by the laser sensor is well beyond 100 feet.) If, for any reason the laser sensor's scan mechanism fails there exists a safety interlock which automatically shuts down the laser beam. The VME site configuration and operating procedures will meet all safety requirements established by ANSI and CDRH and will be approved eye-safe by CDRH for operation in a public setting.

Fencing and Guards: A security fence encompassing the three Sensor Stations, including guy wires, will be deployed. In addition, a security guard will be stationed at the deployment site around-the-clock. Therefore, the necessary precautions have been taken to insure that the public will not have access to the VME-MS.

TRAFFIC

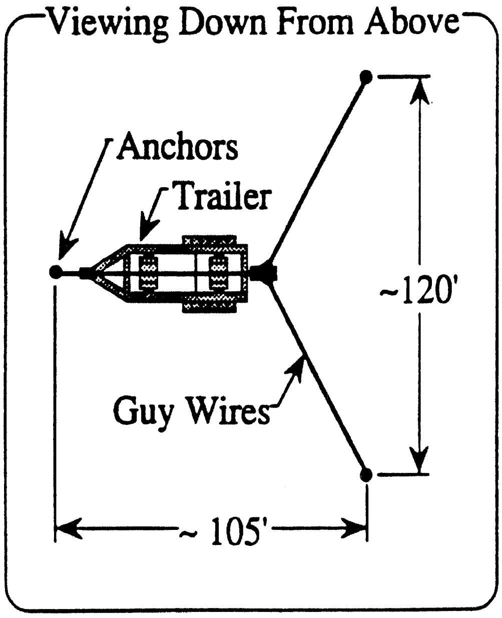
The intent of the VME - Measurement System (VME-MS) is to monitor traffic in it natural setting and not interfere with its normal flow. For a brief period of time after its initiai deployment, the VME-MS may be a temporary distraction to the motorists. We fully expect however, that it will become part of the background for the regular travelers.

Although no part of the VME-MS is deployed closer than 25 feet to the roadway, th process of deploying the VME-MS along the roadside may require temporary closing of some lanes of traffic for survey measurements and installation of road-surface reflectors. Th deployment requirements will not be known until the site layout design is completed. In the event that some lane closures are necessary, the deployment will be done in coordination wit the appropriate State and Ann Arbor officials and at a time to minimize the impact on regular traffic flow. It will be necessary, however, to deploy the system during daylight hours.

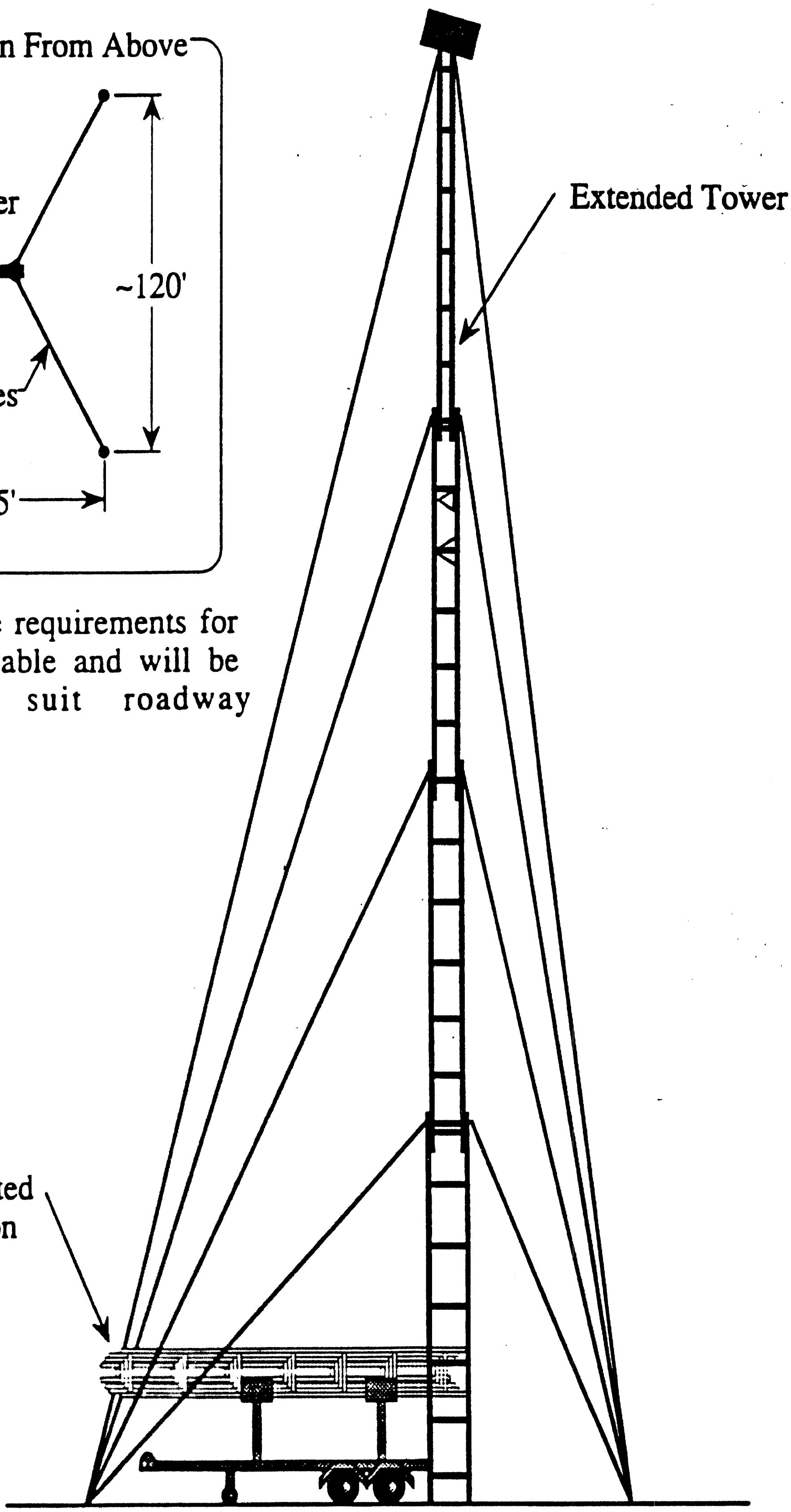
SCHEDULE

Our current plans indicate that the VME-MS will be ready for roadside deployment the last week of April, 1994 and will be deployed for a period of approximately six (6) weeks. Th estimated time for roadside deployment will be revised monthly based on the development progress made during the previous month. The deployment period may also change slightl depending on the performance of the deployed system and the variety of traffic conditions that have been monitored. The data will be reviewed on a weekly basis to determine if any chang are required in deployment plan.

Trailer-Mounted Guyed-Tower Manufactured Alama Tower Co.



Note: The space requirements for guying are variable and will be finalized to suit roadway constraints.



CITY OF ANN ARBOR, MICHIGAN
BUILDING DEPARTMENT
100 N. FIFTH AVENUE 994-2674

BUILDING PERMIT

APPLICANT COPY

AMOUNT PAID

THIS PERMIT NOT VALID UNLESS PROPERLY RECEIPTED BY CASHIER

VALIDATION

APPLICANT E.R.I.M.

DATE 8-3 19 94

PERMIT NO. 45643

ADDRESS 994-1200 (NO.) (STREET)

(CONTR'S LICENSE)

PERMIT TO Temporary Trailor (TYPE OF IMPROVEMENT) ( ) (NO.) STORY (PROPOSED USE)

NUMBER OF DWELLING UNITS

AT (LOCATION) 3300 Plymouth (NO.) (STREET)

ZONING DISTRICT ORL

BETWEEN (CROSS STREET) AND (CROSS STREET)

SUBDIVISION 09 23 200012 LOT BLOCK LOT SIZE

45643
BLDG 66.00
P.R. 20.00
CH 86.00
08-03-94 13:51

BUILDING IS TO BE FT. WIDE BY FT. LONG BY FT. IN HEIGHT AND SHALL CONFORM IN CONSTRUCTION

TO TYPE USE GROUP BASEMENT WALLS OR FOUNDATION (TYPE)

REMARKS: (08) Install 3 trailor-conveyed traffic measurement towers and perimeter secarity fence Note: Approval is for 6-week period

AREA OR VOLUME (CUBIC/SQUARE FEET)

ESTIMATED COST $ 10,000

PERMIT FEE $ 66.00
P.R. 20.00

OWNER E.R.I.M.

ADDRESS P.O. Box 134001, Ann Arbor, MI

BUILDING DEPT BY D. Jack Donadlson/mo

FORM NO. BOCA-BP 1969

cc: K. GILBERT.

BUILDING DEPARTMENT

CITY OF ANN ARBOR, MICHIGAN

100 North Fifth Avenue, P.O. Box 8647, Ann Arbor, Michigan 48107

Administration	994-2712	Housing Bureau	994-2678
Appeals Board	994-2696	Plan Review	994-2695
Construction	994-2674	Sign Enforcement	994-2698
Environmental	994-2711	Zoning	994-2697

June 2, 1994

Robert Black
ERIM Facility Planning
P. O. Box 134001
Ann Arbor, Michigan 48113-4001

RE: 3300 Plymouth Road
Appeal 94-Z-23

Dear Mr. Black:

The Zoning Board of Appeals met on Wednesday, May 18, 1994 to hear your appeal for a variance from the regulations of the City Code. The decision of the Board was as follows, and they have asked me to notify you of their action:

1. **Variance of 40 ft. from the 75 ft. front setback granted to allow the installation of three trailer-conveyed, telescoping metal tower units for measurement and monitoring research of normal traffic flows along Plymouth Road, with the following contingency:**

   a. **Project subject to the length of the Building permit.**

2. **Variance of 50 ft. from the 50 ft. height limit in the ORL zoning district granted to allow three 100 ft. high temporary monitoring towers along Plymouth Road.**

Variances granted based on the finding of practical difficulty in that the measurement units must be in the front setback in order to have an unobstructed view of all lanes of traffic, and due to the fact that the Board understands that this temporary installation is a self-limiting project and the sponsor has an end date for the data.

The approval of the above does not relieve you of the responsibility to obtain the required Building Permit and/or Trade Permits from the Building Department before any work can commence.

(over)

JUN 17 1994

If you have any further questions regarding this matter, feel free to contact us.

Very truly yours,

Frances M. McMullan

Frances M. McMullan, Secretary
Zoning Board of Appeals

FMM

cc: City Clerk - City Planning - City Attorney - City Assessor
J. Donaldson, Bldg. Dept. Director
J. DeWolf, Zoning Coordinator
Building Inspector
File & Master Copy

L94Z23.Dec

Federal Aviation Administration:

1) Submission to FAA

2) FAA Response

THIS IS YOUR WORKSHEET *Please Type or Print on This Form* Form Approved OMB NO. 2120-0001

U.S. Department of Transportation
Federal Aviation Administration

Notice of Proposed Construction or Alteration

Aeronautical Study Number

1. Nature of Proposal

A. Type	B. Class	C. Work Schedule Dates
☑ New Construction	☐ Permanent	Beginning 5/1/94
☐ Alteration *	☑ Temporary (Duration 3 months)	End 7/31/94

* If Alteration, provide previous FAA Aeronautical Study Number, if available :

3A. Name, address, and telephone number of individual, company corporation, etc. proposing the construction or alteration. (Number, Street, City, State, and Zip Code)

ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN
3300 PLYMOUTH

(313) 994-1200 EXT. 3576
Area Code Telephone Number

3B. Name, address and telephone number of proponent's representative, if different than 3A. above.

( ) Area Code Telephone Number

2. Complete Description of Structure

Please describe, on a separate sheet of paper if necessary, the proposed construction or alteration.

A. For proposals involving transmitting stations, include effective radiated power (ERP) and assigned frequency of all proposed or modified transmitters on the structure. (If not known, give frequency band and maximum ERP).

B. For proposals involving overhead wire, transmission lines, etc., include the size and the configuration of the wires and their supporting structures.

C. For all proposals, include site orientation, dimensions, and construction materials of the proposed or altered structure.

D. Optional— Describe the type of obstruction marking and lighting system desired for your structure. The FAA will recommend appropriate marking and lighting for the structure in accordance with the standards of Advisory Circular AC 70/7460-1. An FAA marking and lighting recommendation will reflect the minimum acceptable level of conspicuity necessary to warn pilots of the presence of an object. However, the FAA, under certain circumstances, will not object to the use of a system (such as a medium intensity flashing white light system or a dual lighting system) other than the recommended standard.

4. Location Of Structure

A. Coordinates (to hundredths of seconds, if known)	B. Nearest City or Town and State	C. Nearest public or military airport, heliport, flightpark, or seaplane base
Latitude ° ' " : N42 18 14.18	Ann Arbor.	Ann Arbor Municipal Airport
Longitude ° ' " : N83 41 46.18	(1). Distance to 4B: Within Ann Arbor	(1). Distance from structure to nearest point of nearest runway: 6 1/2 Miles
4D. Source of coordinate information for item 4A. above. ☐ USGS 7.5' Quad Chart ☐ Survey ☑ Other Specify WGS84	(2). Direction to 4B: Within Ann Arbor	(2). Direction from structure to airport: Southwest

Indicate the reference datum of the coordinates, if known. ☑ NAD 27 ☐ NAD 83 ☐ Other Specify

4E. Describe, on a separate sheet of paper, the location of the site with respect to highways, streets, airports, prominent terrain features, existing structures, etc. Attach a copy of a U.S. Geological Survey quadrangle map 7.5 minute series (or equivalent) showing the construction site. If available, attach a copy of a documented site survey with the surveyor's certification.

5. Height and Elevation (to nearest foot)

A. Elevation of site above mean sea level.	885 Ft.
B. Height of structure including all appurtenances and lighting above ground or water.	110 Ft.
C. Overall height above mean sea level (A + B)	995 Ft.

FAILURE TO PROVIDE ALL REQUESTED INFORMATION MAY DELAY PROCESSING OF YOUR NOTICE

Notice is required by Part 77 of the Federal Aviation Regulations (14 C.F.R. Part 77) pursuant to Section 1101 of the Federal Aviation Act of 1958, as amended (49 U.S.C. app. § 1501). Persons who knowingly and willfully violate the Notice requirements of Part 77 are subject to a civil penalty of $1,000 per day until the notice is received, pursuant to Section 901(a) of the Federal Aviation Act of 1958, as amended (49 U.S.C. app § 1471(a)) as well as the fine (criminal penalty) of not more than $500 for the first offense and not more than $2,000 for subsequent offenses, pursuant to Section 902(a) of the Federal Aviation Act of 1958, as amended (49 U.S.C. app § 1472(a)).

I HEREBY CERTIFY that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to obstruction mark and/or light the structure in accordance with established marking & lighting standards as necessary.

Date	Typed or Printed Name and Title of Person Filing Notice	Signature
3/14/94	Cedric Mann Student Research Eng.	Cedric Mann

NOTICE TO PREPARER OF FORM

1. Retain this Work Sheet as your copy.
2. Complete and return the remaining copies. Do Not Remove Carbons.
3. Be sure all copies are legible.
4. Print or type all items. The address area will be used to return a copy of this form. (See Above.)
5. Notification to the FAA does not waive the requirements of any other government agency.
6. FAA will acknowledge this notice within 30 days of its receipt.

Agency Display Of Estimated Burden For Notice of Proposed Construction or Alteration

The public report burden for this collection of information is estimated to average 1 hour and one minute per response.

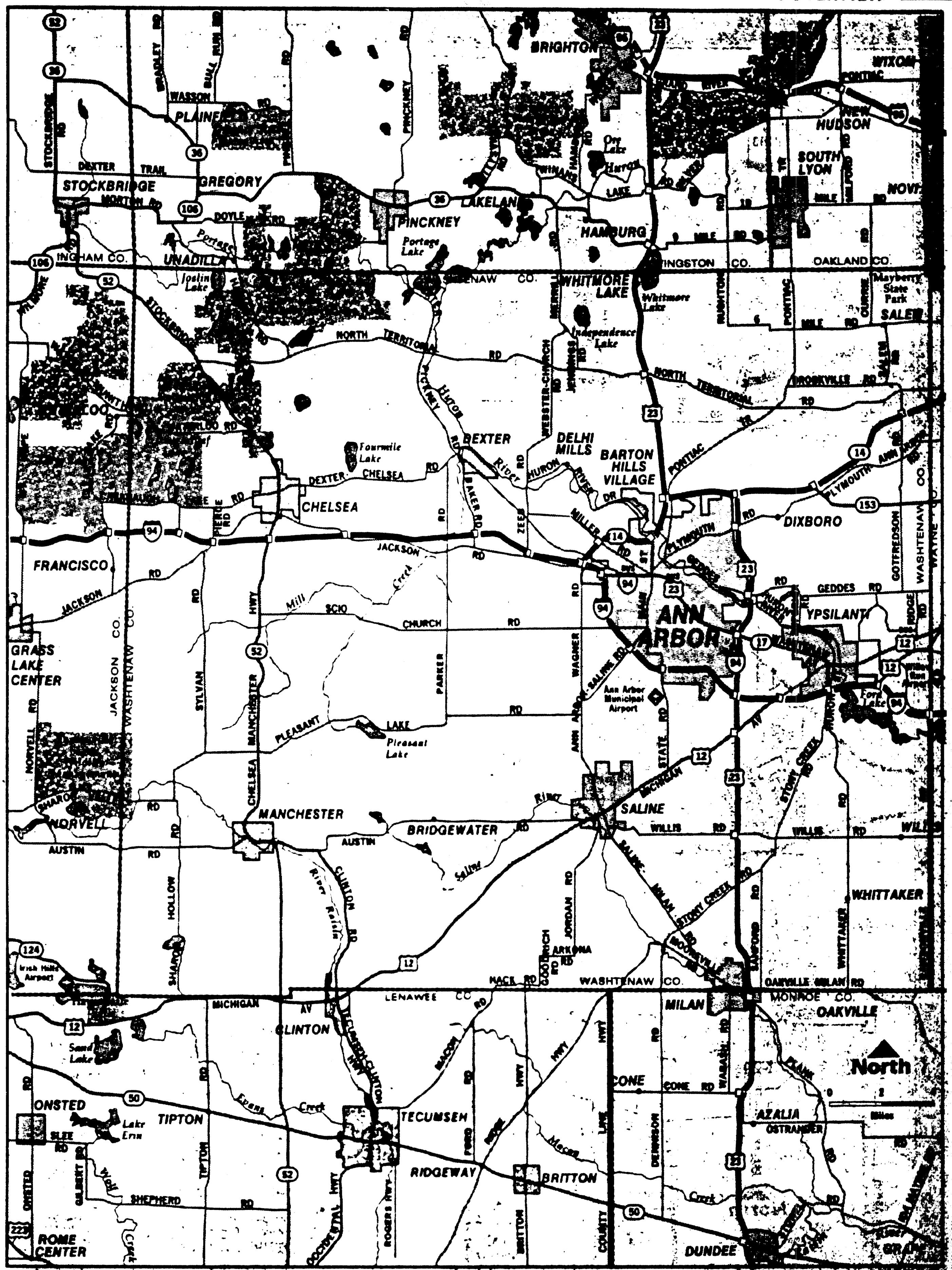
If you wish to comment on the accuracy of the estimate or make suggestions for reducing this burden, please direct your comments to OMB and the FAA at the following addresses.

Please DO NOT RETURN your form to either of these addresses.

Office of Management and Budget
Paperwork Reduction Project 2120-0001
Washington, D.C. 20503

— and —

U.S. Department of Transportation
Federal Aviation Administration
Airspace and Obstruction Evaluation Branch, ATP-240
800 Independence Avenue, SW
Washington, D.C. 20591



MAP BY R.R. DONNELLEY & SONS CO.
CARTOGRAPHIC SERVICES

FEDERAL AVIATION ADMINISTRATION
Great Lakes Region, AGL-530
2300 East Devon Avenue
Des Plaines, IL 60018

In Reply Refer To
AERONAUTICAL STUDY NO.
94-AGL-1689-OE

ACKNOWLEDGMENT OF NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION

PROPONENT:

Environmental Research
Institute of Michigan
3300 Plymouth Rd.
Ann Arbor, MI 48105-2596

CONSTRUCTION LOCATION (NAD 83):
Ann Arbor MI

LATITUDE : 0- 0- 0.
LONGITUDE: 0- 0- 0.

	AGL	AMSL
HEIGHT:	110. ft	995. ft

CONSTRUCTION PROPOSED: 3 Towers Array
FREQUENCY:
EFFECTIVE RADIATED POWER (ERP):

The Federal Aviation Administration acknowledges receipt of notice dated 03/14/94, concerning the proposed constr t or alteration described above.

A study has been conducted under the provisions of Part 77 of the Federal Aviation Regulations to determine whether proposed construction would be an obstruction to air navigation, whether it should be marked and lighted to enhan safety in air navigation, and whether supplemental notice of start and completion of construction is required to r timely charting and notification to airmen. The findings of that study are as follows:

The proposed construction does not require notice to FAA.

If the structure is subject to the licensing authority of the FCC, a copy of this acknowledgement will be sent tc Agency.

>>>> NOTICE IS REQUIRED ANYTIME THE PROJECT IS ABANDONED OR THE PROPOSAL IS MODIFIED <<<<

Remarks:
Coordinates to towers are (from left to right) 42-18-14/83-41-45; 42-18-15/83-41-42; 42-18-16/83-41-38.

-This notice supersedes the ACKNOWLEDGEMENT OF NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION dated April 14, 1994 a revises the remarks to include, structure marking and lighting are not recommended, the determination remains unc

Thomas C Johnson

Signed: Robert J. Woodford
Manager, System Management Branch
for

Issued In: Des Plaines, Illinois
On: 05/27/94

Center for Devices and Radiological Health:

1) Letter acknowledging receipt of ERIM's Model Change Report

2) Model Change Report

FOOD AND DRUG ADMINISTRATION
CENTER FOR DEVICES AND
RADIOLOGICAL HEALTH
2098 GAITHER ROAD
ROCKVILLE, MD 20850

MAY 23, 1995

REFERENCE:
9520655-00

R. KENT GILBERT
VME PROGRAM MANAGER
ERIM
P.O. BOX 134001
ANN ARBOR, MI 48113-4001

THIS IS TO ACKNOWLEDGE RECEIPT OF YOUR DOCUMENT DATED MAY 12, 1995, WHICH WAS FILED PURSUANT TO THE REGULATIONS FOR THE ADMINISTRATION AND ENFORCEMENT OF THE RADIATION CONTROL FOR HEALTH AND SAFETY ACT OF 1968 (TITLE 21, CODE OF FEDERAL REGULATIONS, SUBCHAPTER J) AS THEY PERTAIN TO laser products (except medical devices).

YOUR DOCUMENT HAS BEEN ASSIGNED AN ACCESSION NUMBER OF 9520655, AND HAS BEEN CLASSIFIED AS a report of model change (pursuant to Section 1002.12 of the Regulations referenced above).

FURTHER, THE SUBMITTAL HAS BEEN ASSIGNED AN INFORMAL SUBJECT TITLE OF "MODEL CHANGE REPORT ON LASER PRODUCTS (NON-MEDICAL): FOR VME (VEHICLE MOTION ENVIRONMENT) MEASUREMENT SENSOR SYSTEM."

THIS ACKNOWLEDGEMENT DOES NOT CONSTITUTE APPROVAL OF THE DOCUMENT. IT WILL BE EVALUATED, AND YOU WILL BE CONTACTED IF ANY QUESTIONS OR COMMENTS ARISE IN THE COURSE OF THAT EVALUATION.

THANK YOU FOR YOUR COOPERATION. IF YOU HAVE QUESTIONS OR COMMENTS, PLEASE WRITE TO THE ADDRESS ABOVE OR CALL (301) 594-4654.

JEROME E. DENNIS, ACTING CHIEF
NON-MEDICAL RADIOLOGICAL
DEVICES BRANCH
DIVISION OF ENFORCEMENT
OFFICE OF COMPLIANCE

ERIM P.O. Box 134001
Ann Arbor, MI 48113-4001 313-994-1200

May 12, 1995

Director, Division of Standards Enforcement (HFZ-312)
Office of Compliance
Center for Devices and Radiological Health
2098 Gaither Rd.
Rockville, MD 20850

Subject: Submittal of Report on VME Measurement System

Dear Director:

Enclosed is a Model Change Report on the VME Sensor System. Three of these custom research instruments are being assembled and operated by ERIM. Each sensor includes a certified Class IIIb laser radar subsystem which is installed so that the radiation accessible during operation is Class I.

If your staff has any questions of wishes to examine the product, please contact the undersigned (313-994-1200 ext. 2320).

Yours truly,

R. Kent Gilbert

R. Kent Gilbert
VME Program Manager

Enclosure

LASER PRODUCT REPORT

PART 1

1.1 Manufacturer:

Name ERIM

Address P.O. Box 134001

Ann Arbor, MI 48113-4001

Corresponding official:

Signature ______________________

Name R. Kent Gilbert

Title VME Program Manager

Telephone Number (313)994-1200 ext 2320

1.2 Importing agent (For manufacturers exporting to U.S.)

Not applicable

1.3 Report type:

( ) Initial (XXX) Model Change

( ) Supplement to CDRH Accession No. ______________________

submitted on ______________________
(date)

1.4 Date of this report: ______________________

PART 2

PRODUCT AND MODEL IDENTIFICATION

2.1 List all names, brand names, model numbers and model family designations of the laser product being reported. If the product is sold by other companies under different brand names, also give the names and addresses of the companies, the brand names, and the model numbers, and indicate how the brand names and model numbers correspond with your own brand names and model numbers.

VME (Vehicle Motion Environment) Measurement System

2.2 Is your laser product the result of the modification of a laser product certified by another manufacturer? 1040.10(i)) ( )Yes (**XXX**)No

If yes, identify the manufacturer(s), brand(s), and model number(s).

NOTE: modifications involves any changes to the product that affects its classification, performance or labeling requirements (as required by the standard or an approved variance).

2.3 Does your laser product incorporate an unmodified, certified laser product? (**XXX**)Yes ( )No

If yes, identify the manufacturer(s), brand(s), and model number(s).

Perceptron LASAR Datacamera, Model designations:

ERIM001, ERIM002 & ERIM003

2.4 Does your laser product incorporate a removable laser system or systems as defined in 1040.10(c)(2)?

( )Yes (XXX)No

If yes, identify the manufacturer(s), brand(s), and model number(s).

Is list attached? ( )Yes (XXX)No

2.5 If the laser product, as introduced into commerce, is not supplied with a laser or laser system or the product does not incorporate a laser or laser system, report by manufacturer and model number which laser or laser system, if any, is recommended by you for use with the product.

Not applicable

2.6 If you do not recommend a specific laser or laser system for use with the reported product, state the specifications of the laser or laser system to be incorporated.

Not applicable

PART 3

COMPLIANCE WITH THE LABELING REQUIREMENTS

For each of the following labels required for the product being reported, provide a sample, a facsimile, or a reference if the sample or facsimile is contained in another part of this report. Clearly indicate the locations on the product of all required labels in your response to this Part or to Part 5. Reference to diagrams, photographs, blueprints, product literature, etc., is acceptable.

3.1 Certification label - on all laser products (1010.2)

Is label attached? (**XXX**)Yes ( )No

Location See figure 4. ID Certification in attached manual

3.2 Identification label - on all laser products (1010.3)

Is label attached? (**XXX**)Yes ( )No

Location See figure 4. ID Certification in attached manual

3.3 Warning logotype - required on Class II, III, and IV laser products (1040.10(g)(1),(2),(3),(4),(8),(9),(10))

Is label attached? ( )Yes (**XXX**)No

Location ____________

3.4 Warning label - required on Class IIa laser products (1040.10(g)(1)(i))

Is label attached? ( )Yes (**XXX**)No

Location ____________

3.5 Aperture label(s) - required on Class II, III, IV laser products (1040.10(g)(5),(8),(9),(10) or 1040.11(a)(3))

Is label attached? ( )Yes (**XXX**)No

Location ____________

3.6 Label(s) for non-interlocked protective housings (1040.10(g)(6),(8),(9),(10))

Is label attached? (**XXX**)Yes ( )No

Are labels visible before and after removal or displacement of the protective housing? ( )Yes ( )No

Location **Label is visible at bottom of tower before tower is raised or lowered**

3.7 Label(s) for defeatably interlocked protective housings (1040.10(g)(7),(8),(9),(10))

Is label attached? ( )Yes (**XXX**)No

Are labels visible before and after removal or displacement of the protective housing? ( )Yes ( )No

Location ____________________

3.8 Label(s) for optionally interlocked protective housings. (See Notice of March 2, 1977, dealing with optional interlocks.)

Is label attached? ( )Yes (**XXX**)No

Are labels visible before and after removal or displacement of the protective housing? ( )Yes ( )No

Location ____________________

PART 4

COMPLIANCE WITH THE INFORMATIONAL REQUIREMENTS

4.1 Submit copies of user and servicing information (manuals). If the manuals are very extensive, submit only those portions that confirm compliance with Section 1040.10(h) and that permit understanding how your laser product functions.

NOTE: These materials may also be used in the product description required by Part 5.

Are copies attached? (XXX)Yes ( )No

4.2 Submit copies of any catalogs, specification sheets, and descriptive brochures for Class IIa, II, III, and IV laser products.

NOTE: This material is needed to demonstrate compliance with Section 1040.10 (h)(2), which states that a reproduction of the warning logotype is required in all catalogs, specification sheets, and descriptive brochures.

Are copies attached? ( )Yes (XXX)No

PART 5

DESCRIPTION OF THE PRODUCT

5.1 Describe the product and its function. You may refer to brochures and manuals submitted with this report. If necessary, include drawings or photographs adequate to document compliance of the product with the performance and labeling requirements.

Is description attached? (XXX)Yes ( )No

5.2 Describe the external and internal laser radiation fields and paths.

Is description attached? (XXX)Yes ( )No

5.3 List the functions performed during operation and indicate those collateral and laser radiation fields specified in Part 6 to which human access is possible when those functions are being performed. (See definition of human access - Section 1040.10(b)(15)).

See attached

5.4 List the functions performed during maintenance and indicate those collateral and laser radiation fields specified in Part 6 to which human access is possible when those functions are being performed.

See attached

5.5 List the functions performed during service and indicate those collateral and laser radiation fields specified in Part 6 to which human access is possible when those functions are being performed.

See attached

Attachment to 5.1

The "product" is a VME installation that includes a Perceptron Datacamera, telescoping tower, and control console, all mounted to a trailer and surrounded by a chain-link fence. This is a research system that is to be installed adjacent to roadways in order to monitor and record data on vehicle movements. More than one VME sensor station may be used at a given location to provide broader coverage as noted in the figures and manual.

The tower is mounted to the trailer and it extends up to 110 feet above the ground. The Datacamera laser radar is mounted on a platform at the top of the tower in order to obtain the desired field of view on the road. Depending on the site geometry, the tower will be raised to a height of 75 to 110 feet. The Datacamera field of view will be directed toward the road as shown in the figures, so that the total distance from the window to a location where a person could be present is greater than the height of the tower.

The equipment is installed and operated by research technicians and engineers. When the equipment is being set up at a new location, the Datacamera is mounted to the tower platform with the Datacamera cables disconnected from the console. The tower is then raised to the desired height and guy wires from the platform and tower are anchored to the ground. Only then are the electrical cables connected so that the Datacamera can be operated. The Datacamera could be operated at ground level, but only during service with additional safety precautions taken. The Datacamera would not be operated during the time that the tower is being raised for mechanical and electrical safety reasons, in addition to any laser safety concerns.

The installation is surrounded by a 6' high chain-link fence, and a guard is present whenever the equipment is powered. The area that is fenced includes the ground below any portion of the beam path that could exceed the Class I limits. Since the distance from the Datacamera window that is required for the accessible energy to drop below the Class I limits is approximately 33' and the operating height of the tower is 75'- 110', a large safety margin is present even ignoring the horizontal component of the distance.

The Perceptron Datacamera has been certified as a Class IIIb device by its manufacturer. Thus the housing contains a key switch, warning labels, and other items applicable for that class.

Protective housing labels on the base of the tower and at the tower controls will warn of the hazard with the tower lowered. An ERIM ID/certification label will also be visible on the electronics enclosure.

Attachment to 5.2

The Datacamera output is present at the Datacamera window. It would be accessible during service if the Datacamera is powered when near ground level.

Higher levels of laser energy may be present inside the Datacamera housing - see the Perceptron report for that information. That energy should be accessible only to Perceptron personnel, as field service by ERIM does not include opening the housing.

The laser energy that could be accessible during operation would be at a distance of well beyond 75' from the Datacamera. As shown in Section 6.1, that energy would be Class I.

Attachment to 5.3

Operation consists of turning on the Datacamera and adjusting the controls on the console in the trailer. See the manuals for details.

The Datacamera output would be emitted through the Datacamera window, however, the height above the ground would ensure that there is no accessible laser energy which exceeds the Class I limits. Beams which exceed Class I would be in excess of 40' above ground level, and the entire area under that portion of the beam pattern is fenced to control access.

Attachment to 5.4/5.5

Installation could be considered either maintenance or service as it is to be performed only by trained personnel. It includes mounting the Datacamera on the platform, raising the tower to the desired height, anchoring the guy wires, and aligning the output pattern as required for the roadway configuration.

Service also includes removal of the Datacamera, testing of the output on the ground, cleaning the window, and performing the other procedures specified in the ERIM manual.

The Datacamera output could be accessible during service by ERIM personnel. Higher levels may be accessible inside during service by Perceptron personnel as described in the Perceptron report.

PART 6

LEVELS OF ACCESSIBLE LASER RADIATION AND CLASSIFICATION OF THE LASER PRODUCT

6.1 Give the specifications of all laser radiation fields described in Part 5 to which human access is possible during **operation.** Include at least the following (if applicable):

- Wavelength(s);
- Maximum peak and maximum average radiant power and emission durations, pulse durations, and pulse rise and fall times;
- Maximum pulse rate;
- Maximum irradiance or radiant exposure;
- Maximum radiance or integrated radiance; and
- Divergence

See attached

Are specifications attached? (**XXX**)Yes ( )No

6.2 Indicate the Class of the laser product, based on your response to Part 6.1.

(**XXX**)Class I ( )Class IIa ( )Class II

( )Class IIIa ( )Class IIIb ( )Class IV

6.3 Give the specifications of all laser radiation fields described in Part 5 to which human access is possible during **maintenance.**

See attached

Are specifications attached? (**XXX**)Yes ( )No

6.4 Give the specifications of all laser radiation fields described in Part 5 to which human access is possible during service.

See attached

Are specifications attached? (**XXX**)Yes ( )No

6.5 Describe all collateral radiation associated with the product. Report the source(s) and levels and describe where and under what circumstances such radiation is accessible.

There is no collateral radiation, other than that which might be present inside the Datacamera housing. See the Perceptron report.

Are specifications attached? ( )Yes (**XXX**)No

Attachment to 6.1 and 6.3

The following calculations are provided to show the distance from the Datacamera window at which the accessible radiation drops below the Class I limits.

DEFINITION AND DATACAMERA PARAMETERS

The following parameters were supplied by the Datacamera manufacturer:

ω = rotation rate of scanning polygon = 229 Hz, with the scan oriented in the vertical direction

P = modulated (average) power in the emitted beam = 0.4 W (peak power is specified at 750 mW with 50% modulation)

a = beam diameter at the apparent source = 0.19 cm

b = divergence of scanning beam = 0.0021 rad

n = number of facets on scanning polygon = 6, orthogonal to the rotation axis

λ = wavelength = 985 nm

FOV = field of view = 50° horizontal and 35° vertical

The following definitions apply to these calculations:

R = distance from the apparent scan origin to the point of access to the beam (cm)

D = beam diameter at distance R (cm)

DC = duty cycle of the beam in measurement aperture at distance R

t = time for beam to scan through measurement aperture (s)

GEOMETRIC CONSIDERATIONS

We will use a 5 cm measurement aperture for this evaluation since binoculars or other collecting optics could be used in the VME environment. If the beam diameter D is less than 5 cm, the duty cycle of the beam during one vertical scan at a distance R is:

$$DC = D/(4\pi R/n) = 5/(4\pi R/n) = 0.4\ n/R.$$

The time for a single pulse to pass through that aperture is:

$$t = DC/(n\ \omega) = 0.4/(R\ \omega).$$

6.1/6.3 (Cond.)

CLASSIFICATION CALCULATIONS - SINGLE SCAN

From Table I of the CDRH regulations, the Class I limit for pulses of less than 18 us at the 985 nm wavelength is:

$$E_{lim} = 0.2 \text{ uJ} \times 3.58 = 0.716 \text{ uJ}.$$

The exposure from a pulse of power P for a time period t is:

$$E_{exp} = P \times t.$$

Setting the exposure equal to the limit, substituting for t, and solving for R yields:

$$R = 5.59 \times 10^5 \, P/\omega \text{ cm}.$$

For values of P = 0.4 W and ω = 229, the distance to drop below the Class I limit would be:

R = 979 cm = 32.6'.

The above analysis assumed that the time of a single pulse was less than 18 us and assumed that the beam diameter was less than the 5 cm diameter of the measurement aperture at the distance R. To check those assumptions, consider the following:

$$t = 0.4/(R\,\omega).$$

For ω = 229 Hz, we can determine that the value of t will be less 18 us for any R greater than:

R = 0.4/(18 us x 229) = 97 cm = 3.2'.

The diameter D at a distance R can be expressed as:

$$D = a + b\,R = 0.19 + 0.0021\,R \quad \text{(cm)}.$$

The distance required for the beam to exceed the 5 cm measurement aperture is:

R = (5 - 0.19)/0.0021 = 2290 cm = 76'.

Thus the beam would have a pulse time at R = 32.6' that is much shorter than 18 us, and the emitted beam diameter would be much smaller than the 5 cm measurement aperture at that distance.

The 32.6' determined above has an added safety factor as it did not include the optical losses due to the (75-80%?) transmission of any collecting optics that could be used to view the energy.

6.1/6.3 (Cond.)

CLASSIFICATION CALCULATIONS - AVERAGE POWER

In addition to the analysis for the pulsed output, it is necessary to verify that the limits on average power at 979 cm are not exceeded.

The Datacamera scans at a rate of 10 frames/sec. If we assume that there is only one scan/frame in the 5 cm measurement aperture at that distance and the scan always passes through the diameter of the aperture (worst case), then the average power would be:

$$P_{ave} = P \times t \times 10 = 0.4 \times 0.4/(979 \times 229) \times 10 = 7.2 \text{ uW}.$$

That value is far below the Class I average power limit of:

$$P_{lim} = 0.39 \times 3.58 \times 100 = 140 \text{ uW}.$$

To verify that only one scan/frame appears in the measurement aperture, we can determine the scan separation at the distance R from the parameters provided by Perceptron. The camera scans vertically and the frame is 50° in the horizontal field of view. For a rotation rate of 229 Hz and a 6-facet polygon, there are 6 x 229 = 1374 scans/second or 137 scans/frame at the 10 frame/sec rate. At a distance of 979 cm, the horizontal dimension of the 50° field of view would be 2 x 979 tan(50°/2) = 913 cm. The line separation would be:

$$\text{Line Sep} = (913 \text{ cm/frame})/(137 \text{ scans/frame}) = 6.66 \text{ cm/scan}.$$

Since the spacing is 6.6 cm, only one scan would enter the 5 cm measurement aperture during each frame.

Although the Datacamera software allows the scan width to be programmable, the system will be operated only at the maximum angle of 50°. The data analysis software monitors the presence of reference points that have been placed in the scan field, and if they are missing for more than one second (indicating that the camera is not scanning the full field of view), then the system is shut off.

PRODUCT CLASSIFICATION

The Datacamera is not to be powered during operation unless it is raised on the tower to a height of 75-110' and the platform and tower are stabilized with guy wires. The product is operated only by trained research technicians and engineers, as only a few VME units are to be built for this research project. The fence maintains all observers at a distance of at least 33' from the base of the tower, and with the 75' operating height, the spacing from the Datacamera to an observer would be at least 82'. Since the output is Class I beyond a distance of 32.6', any radiation that could be accessible during operation would be far below the Class I limits.

Attachment to 6.4

The Class IIIb output of the Datacamera could be accessible to ERIM personnel during service. See the report from Perceptron for a description of any laser energy accessible inside the housing.

PART 7

COMPLIANCE WITH THE PERFORMANCE REQUIREMENTS

7.1 Protective housing - Required for all laser products (1040.10(f)(1))

7.1.1 Explain by what means the levels of all laser radiation accessible during operation are maintained within the lowest class that can be used to perform the functions of the product. No explanation is needed for radiation less than the accessible emission limits of Class I.

Product is Class I

Is additional information attached? ( )Yes (**XX**)No

7.1.2 If any collateral radiation in excess of the limits specified in Table VI is accessible during operation, explain why such accessibility is necessary for the product to perform its intended functions. For laser products in which the protective housing prevents human access to collateral radiation in excess of the limits specified in Table VI, explain how the protective housing prevents such access.

There is no collateral radiation accessible during operation

7.2 Safety interlocks - Required for all laser products (1040.10(f)(2)(i))

7.2.1 Provide a detailed electrical and mechanical diagram of each interlock incorporated into the laser product for radiation safety. Describe how each such interlock prevents access to laser and/or collateral radiation when the protective housing is opened.

As there is no access to laser energy above Class I in the VME installation during operation or maintenance, interlocks are not required.

Are elect/mech diagrams attached? ( )Yes (**XX**)No

Is additional information attached? ( )Yes (**XX**)No

7.3 Defeatable safety interlocks - Applicable to all laser products (1040.10)(f)(2)(ii) and (iii))

Not applicable

Is additional information attached? ( )Yes (**XX**)No

7.4 Safety interlock failure - Applicable to all required safety interlocks (1040.10(f)(2)(iii) that prevent access to Class IIIb or IV levels of laser radiation.

Not applicable

Is additional information attached? ( )Yes (**XX**)No

7.5 Remote interlock connector - Applicable to Class IIIb or IV laser systems (1040.10(f)(3))

7.5.1 Describe the electrical and mechanical construction and operation of the remote interlock connector. Give its circuit and physical locations.

Not applicable for Class I

Are elect/mechanical diagrams attached? ( )Yes (**XX**)No

Is additional information attached? ( )Yes (**XX**)No

7.6 Key control - Required for Class IIIb or IV laser systems (1040.10(f)(4))

7.6.1 Describe the electrical and mechanical construction of the key-actuated master control.

Not applicable for Class I

Are elect/mechanical diagrams attached? ( )Yes (**XX**)No

Is additional information attached? ( )Yes (**XX**)No

7.7 Laser radiation emission indicator - Required for Class II, IIIa, IIIb, or IV laser systems (1040.10(f)(5))

7.7.1 Describe in detail the mechanical and electrical characteristics of all emission indicators installed pursuant to Section 1040.10(f)(5)(i) or (ii) and give their locations.

Not applicable for Class I

Are elect/mechanical diagrams attached? ( )Yes (**XX**)No

Is additional information attached? ( )Yes (**XX**)No

7.7.2 Record in the appropriate space below the length of time each emission indicator of Class IIIb and IV laser systems is actuated prior to the emission of accessible laser radiation.

N/A Seconds Minutes

7.8 Protective eyewear - Applicable to Class II, IIIa, IIIb, or IV laser systems (1040.10(f)(5)(iv)). State whether protective eyewear is supplied or recommended for use with the laser system. If so, confirm that any visible emission indicator can be clearly seen through the protective eyewear.

Is protective eyewear supplied? ( )Yes ( )No

Is it recommended? ( )Yes ( )No

Can visible emission indicators be seen through the eyewear? ( )Yes ( )No **Not applicable**

7.9 Beam attenuator - Required for Class II, IIIa, IIIb, or IV laser systems (1040.10(f)(6))

7.9.1 For each beam attenuator, describe the mechanical and electrical characteristics and how, when actuated, the attenuator prevents access by any part of the human body to all laser and collateral radiation in excess of the accessible emission limits of Class I and Table VI.

Not applicable for Class I

Are elect/mechanical diagrams attached? ( )Yes (**XX**)No

Is additional information attached? ( )Yes (**XX**)No

7.9.2 Discuss the permanency of attachment of each beam attenuator

N/A

Is additional information attached? ( )Yes (**XX**)No

7.10 Location of controls - Applicable to Class II, IIIa, IIIb, or IV laser products (1040.10(f)(7))

Explain how the location of each of the operation and adjustment controls of the laser product is such that human exposure to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI is unnecessary for operation or adjustment of such controls.

Not applicable for Class I

Is additional information attached? ( )Yes (**XX**)No

7.11 Viewing optics - Applicable to all laser products (1040.10(f)(8))

7.11.1 State whether all laser and collateral radiation accessible by virtue of viewing optics, viewports, and display screens incorporated into the reported model of laser product is less than the accessible emission limits of Class I and Table VI during operation and maintenance.

REMINDER: Report in Part 5 the locations and identification of laser and collateral radiation made accessible by viewing optics, viewports, and display screens. In Part 6, report the highest levels.

There are no viewing optics in the product

Is additional information attached? ( )Yes ( )No

7.11.2 Describe in detail, using diagrams or photographs and radiation transmission or reflection spectra, each shutter or variable attenuator incorporated into viewing optics, viewport, or display screens. Describe how exposure of the eye to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI is prevented whenever the shutter is opened or the attenuator is varied.

Not applicable

Is additional information attached? ( )Yes (**XX**)No

7.11.3 Describe how opening the shutter or varying the attenuation is prevented when exposure of the eye to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI is possible upon failure of such means as required by Section 1040.10(f)(8)(ii).

Not applicable

Is additional information attached? ( )Yes (**XX**)No

7.12 Scanning safeguard - Required for certain laser products with scanned laser radiation (1040.10(f)(9))

Describe the mechanical, electrical, and functional characteristics of any required scan failure safeguard.

NOTE: A safeguard is required when scan failure would cause the product to exceed the emission limits of the class of the product, or in the case of Class IIIb or IV laser products would cause the accessible emission limits of the class of the scanning level to be exceeded.

See the Perceptron report for a discussion of the scanning safeguard.

Are elect/mechanical diagrams attached? ( )Yes (**XX**)No

Is additional information attached? ( )Yes (**XX**)No

7.13 Medical laser product - Applicable to Class III or IV medical laser products intended for in-vivo surgical, therapeutic or diagnostic irradiation of the human body.

7.13.1 Describe the means incorporated into the product to measure the level of laser radiation intended for irradiating the human body; include circuit diagrams and optical system diagrams.

Not applicable

Is additional information attached? ( )Yes (**XX**)No

7.14 Manual Reset - Applicable to Class IV laser systems manufactured after August 20, 1986.

Provide the circuit and physical description and location of the means provided to require manual restart following interruption of emission following power failure or deactivation through the remote interlock connector.

Not applicable for Class I

Is a circuit diagram attached? ( )Yes (**XX**)No

PART 8

QUALITY CONTROL TESTS AND TESTING PROCEDURES FOR COMPLIANCE

8.1 Attach, and identify as attachments to Part 8, samples of all documents that describe, specify, or relate to procedures or tests used to ensure compliance of your reported product with the standard, including compliance with all performance, labeling, and informational requirements. These may include (check those items attached):

( ) specification controls for critical components,

( ) manufacturing and assembly control procedures,

( ) inspection and test control procedures,

( ) assembly and test traveler forms,

( ) inspection and test reports and checklists, and/or

( ) other(s) ______________________________
(specify)

8.2 If formal quality control and testing procedures have not been implemented or are not sufficient to assure that your product(s) will comply with the standard, explain how you assure that your products comply and submit supporting documentation.

See the attached procedure for the low-quantity

production

Is add'l information/documentation attached? (**XXX**)Yes ( )No

NOTE: Section 1010.2(c) requires that certification be based on a test, in accordance with the standard, of each unit or on a program in accordance with good manufacturing practices. Failure to maintain an adequate testing program may result in disapproval of the program by CDRH.

PART 9

LIFE AND ENDURANCE TESTING

Describe those tests and controls used to ensure that the reported product will remain in compliance with the standard during its useful life. Items to be addressed include:

9.1 Dimensional stability and rigidity of mechanical parts and assemblies such as housings and mounts

See attached

Is add'l information/documentation attached? (**XXX**)Yes ( )No

9.2 Design and ratings of electrical and electronic components

See attached

Is add'l information/documentation attached? (**XXX**)Yes ( )No

9.3 Environmental stability of components such as filter materials, coatings, and adhesives

Not applicable

Is add'l information/documentation attached? ( )Yes (**XXX**)No

9.4 Design and testing of features designed to meet performance requirements

See attached

Is add'l information/documentation attached? (**XXX**)Yes ( )No

9.5 Other factors that might affect your product's radiation safety

NOTE: Maintenance and/or service instructions must include schedules for maintenance and replacement of those components related to the compliance of the product that may be expected to be replenished or replaced during the life of the product.

See attached

Is add'l information/documentation attached? (**XXX**)Yes ( )No

Attachment to Section 9

The output power level is established by the Datacamera manufacturer, however, there is a considerable safety margin in the accessible radiation below the Class I limits during operation.

See the report from the Datacamera manufacturer for a discussion of the adequacy of the Datacamera protective housing, the scan failure mechanism, and the labels and Class IIIb features on that housing.

Thus no special life tests are required at ERIM.

PART 10

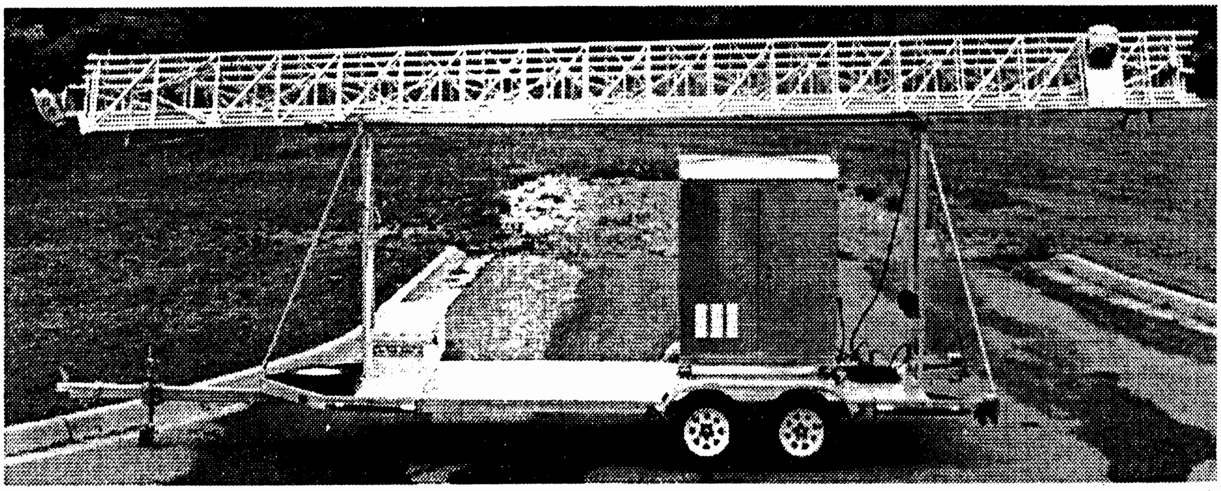
INSTRUMENTATION AND CALIBRATION

Describe those tests and controls used to ensure that the reported product will remain in compliance with the standard during its useful life.

As the laser energy that is accessible during operation, maintenance and service is determined from the data specified by the Datacamera manufacturer, no calibrated measurements are needed.

Is add'l information/documentation attached?(   )Yes   (**XXX**)No

Vehicle Motion Environment Measurement System (VME-MS)



Operator's Manual

(See Appendix E)

Appendix E

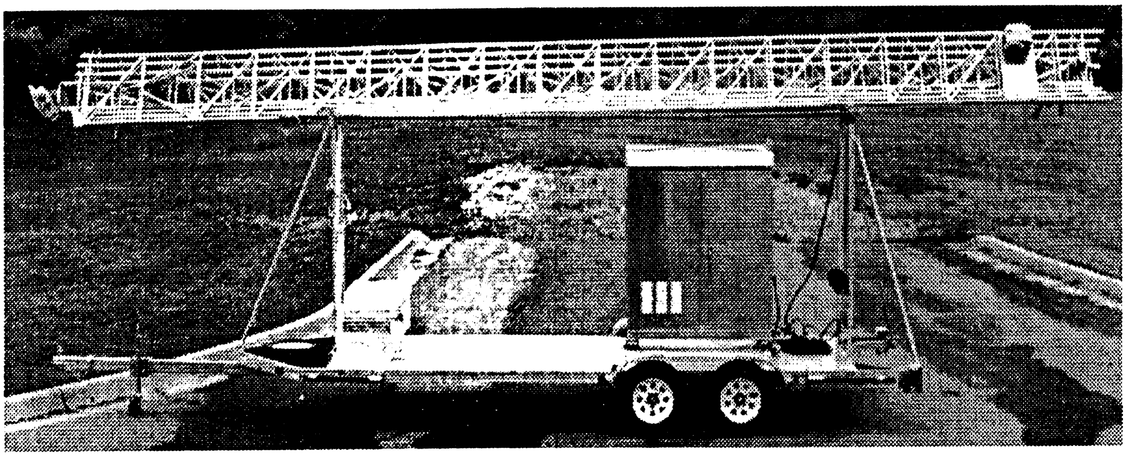
VME-MS Operator's Manual

This Appendix contains the VME-MS Operator's Manual providing necessary information for deployment and operation of the VME measurment system.

249800-9-F

Vehicle Motion Environment Measurement System (VME-MS) Operator's Manual

NOVEMBER 1995



Prepared for:

University of Michigan
Office of Contracts Administration
Ann Arbor, MI 48109-1248

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15. Supplementary Notes		

16. Abstract

This operator's manual provides the user with the necessary information for the successful deployment and operation of the Vehicle Motion Environment Measurement System (VME-MS). The VME-MS is a configuration of multiple sensor stations, each consisting of a guyed tower, an infrared imaging laser radar, a video camera and supporting electronics--all supported by a trailer assembly for the VME-MS at selected roadside locations.

17. Key Words vehicle motion environment, VME, measurement system, MS, sensor, infrared, imaging, laser radar	18. Distribution Statement Approved for public release; distribution is unlimited

19. Security Classif. (of this report) unclassified	20. Security Classif. (of this page) unclassified	21. No. of Pages 83	22. Price

Table of Contents

List of Figures

1.0 Introduction

This manual provides the user with the necessary information for the successful deployment and operation of the Vehicle Motion Environment Measurement System (VME-MS). The VME-MS is a configuration of multiple sensor stations, each consisting of a guyed tower, an infrared imaging laser radar, a video camera and supporting electronics all supported by a trailer assembly for the VME-MS at selected roadside locations (see Figure 1).

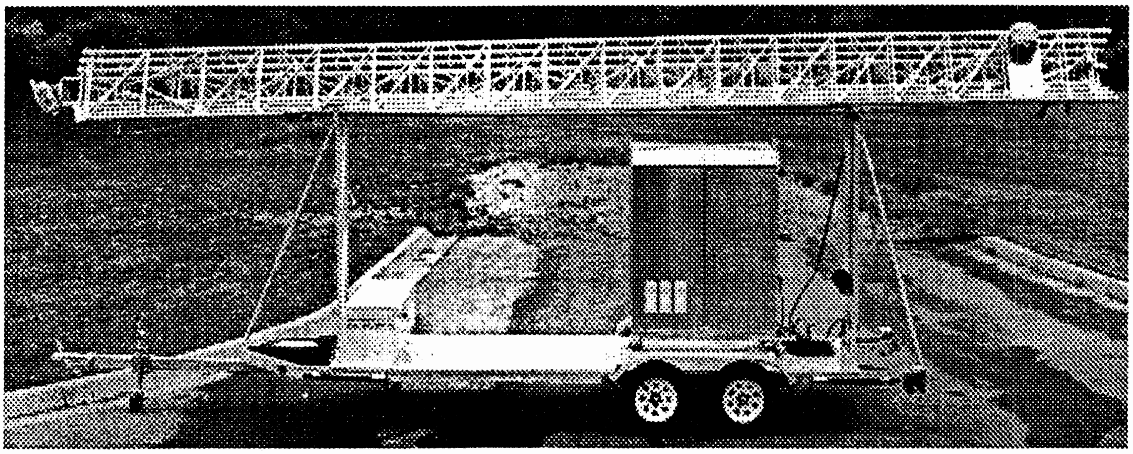


Figure 1. The VME-MS Sensor Station

Operation can occur in one of two modes: Diagnostic or Turnkey. The system is operated in diagnostic mode by trained engineers and scientists for the purpose of system initialization, assessing system performance and for gathering data necessary for track file algorithm refinement and improvement. The Turnkey mode is the normal operating mode of the system, and should be operated by personnel trained in system operations and apprised of all safety regulations.

All personnel operating the VME-MS in either diagnostic or turnkey mode must be trained and knowledgeable staff. The procedural and precautionary instructions embodied in this report, are for system deployment, operation, and removal, and must be strictly adhered to in both diagnostic and turnkey scenarios.

WARNING: No one shall operate the VME-MS unless previously instructed in proper procedures and precautionary matters

This manual is organized in five sections and three appendices. In general, the sections are geared toward providing precautionary measures, safety considerations, and examples of deployment scenarios. Section 2 presents safety issues related to the infrared imaging laser radar deployed at the top of each 100 ft. tower. Section 3 of this manual outlines considerations for selecting a deployment site. Section 4 presents the process of obtaining the necessary approvals from local government agencies. Section 5 details the mechanics of deploying a VME-MS. In contrast to the body of the manual, the appendices include detailed step-by-step rules and procedures required for successful and safe operation of the VME-MS. Specifically, Appendix A contains additional laser safety regulations enforced by individual states, Appendix B contains the laser sensor operation/safety manual provided by the sensor manufacturer, and Appendix C contains the detailed deployment instructions for the trailers, telescoping towers, anchors, and guy wires provided by the manufacturer.

2.0 Laser Safety

This section describes the necessary precautions for operating the imaging laser radar (LASAR Datacamera™), which houses an infrared laser diode. The LASAR Datacameras™ were custom-manufactured by Perceptron and provided to ERIM as Class IIIb certified sensors for incorporation as a subsystem into the VME-MS traffic monitoring system. These Class IIIb certified laser sensors are deployed atop 100 foot high towers. High towers, security fences, and 24-hour security guard surveillance ensure Class I radiation levels at all accessible regions during operation. In fact, radiation levels are considered eye-safe beyond five feet from the aperture, and beyond 33 feet when viewed with 7X magnification binoculars. Figure 2 depicts the safe and hazardous regions in the proximity of the sensor in its recommended deployment configuration. The following precautions shall be posted at each sensor station to ensure laser safety during deployment, operation, and removal (See Section 5.0 and Appendix C for detailed procedure). The protective housing (DANGER) label, visible at the base of the tower and at the controls, and the ID certification label located on the electronics console are shown in Figures 3 and 4, respectively.

WARNING: Do not physically connect power cables until the tower is at its operational height.

CAUTION: Use of controls or adjustments or the performance of procedures other than those specified in the operators manual may result in hazardous invisible radiation exposure.

These warnings shall be explicitly reproduced in their entirety and clearly visible at the base of each station.

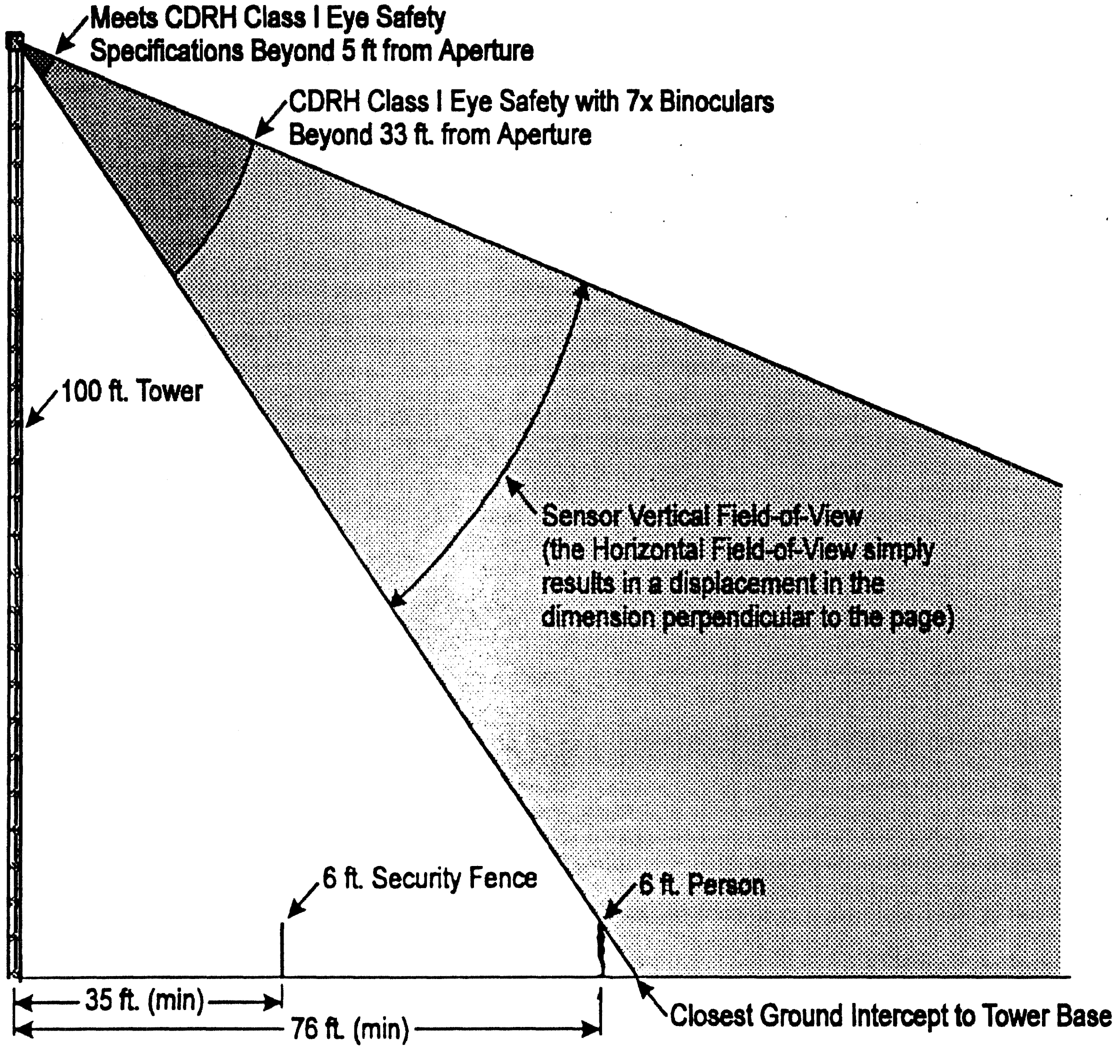


Figure 2. Safety Region

Figure 3. Protective Housing Label

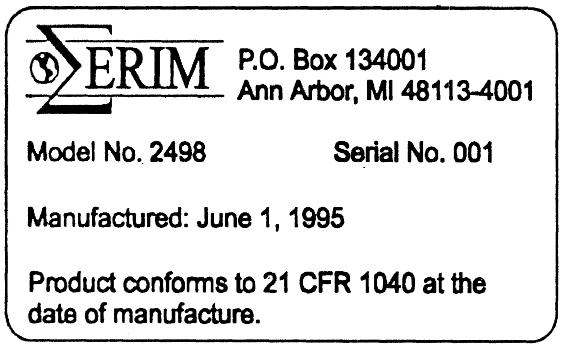


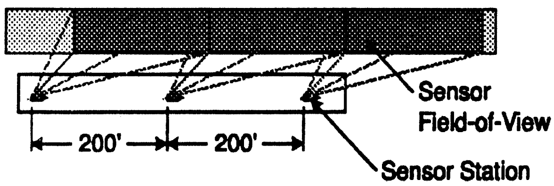
Figure 4. ID Certification Label

All cables connecting the electronics enclosure to the sensor head must be disconnected at the electronics enclosure until the tower is fully deployed. This precaution is necessary to ensure that hazardous radiation cannot be accessible during deployment of the Sensor Stations and to protect the cables from excessive strain during tower extension.

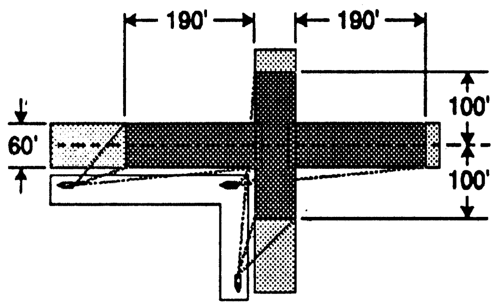
The imaging laser radars are scanning systems. As long as the laser beam is scanned, the above safe ranges apply. If for any reason the polygon mirror scan mechanism should fail, there exists an electronic safety interlock which immediately shuts off power to the laser, thus preventing hazardous exposure. (See Appendix B, the Perceptron Datacamera™ Operation Manual, for more detail).

3.0 Site Selection

The VME system has been designed to allow for a wide variety of configurations to promote maximum flexibility in selecting a site based on traffic phenomena of interest. This section presents issues and requirements that must be addressed when selecting a deployment site. Two generic site layouts are shown in Figure 5. Figure 5a illustrates the nominal configuration which covers approximately 600 feet of contiguous roadway. Figure 5b illustrates how the same three sensor stations could be configured to cover a four-way intersection. The actual procedures for deployment and removal of the installation are presented in Section 5.0 and Appendix C.



(a) Three Sites for Contiguous Coverage of Roadway



(b) Three Sites Spaced Around Intersection

Figure 5. Example Site Layouts

3.1 Physical Layout

The deployment site should be selected to maximize the "number of samples on the roadway" subject to the constraints presented in this section. ERIM has developed a software spreadsheet tool which allows the user to trade-off various parameters to find

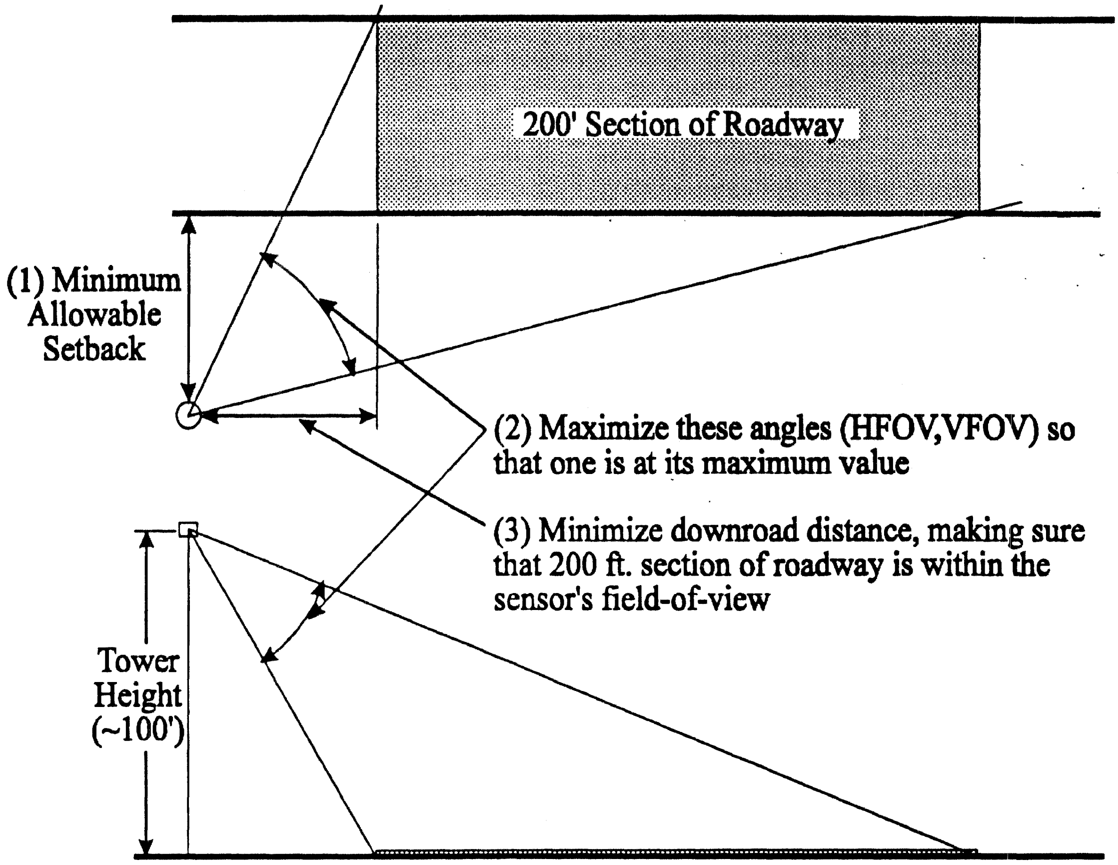


Figure 6. Procedure for Obtaining the Optimal Geometry

the best geometry for a given site. Given a collection site, the software allows a designer to configure the sensor stations in such a way as to maximize the quality of the data collected. Figure 6 shows the general procedure for obtaining the best geometry at a given site. The following items all go into the design of the physical site layout.

Obscurations: There should be a clear line of sight from the Laser Sensor Head to the section of roadway being monitored. Any obscurations due to trees, buildings, overpasses, etc. will degrade the ability of the VME-MS to produce seamless track files. Substantial obscuration will severly limit the quality of the track-file data.

Terrain grade: The VME-MS has been designed to accommodate a wide variety of viewing geometries and therefore is not very sensitive to terrain grade from an imaging and measurement perspective. Tower leveling and guying criteria, however, must be considered when selecting a terrain with a large gradient. Wherever possible a site with minimum relief is best.

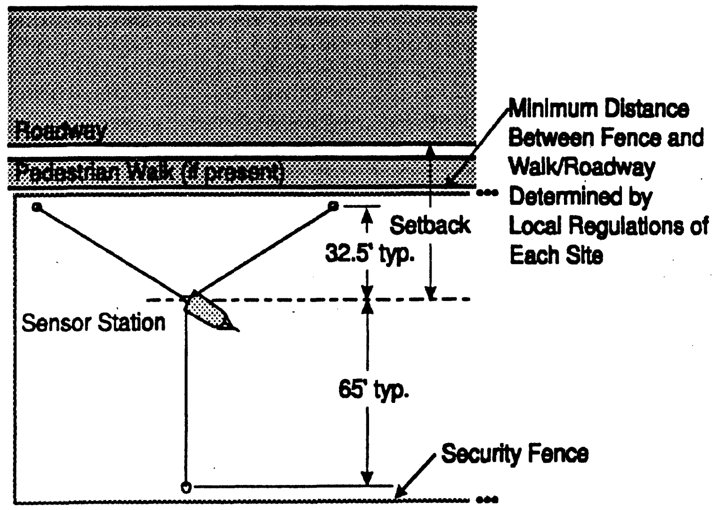


Figure 7. Setback Constraints

Setback: From a measurement fidelity perspective it is desirable to be as close to the area of interest as possible. Area coverage, beam footprint, right-of-way, guy wire locations and laser safety impose constraints on the closest available setback. Figure 7 illustrates the manner in which these constraints dictate the minimum obtainable setback.

Tower Separation: The separation between towers should be chosen such that the multi-tower deployment geometry will provide contiguous coverage of a stretch of roadway. It is also advantageous to include some overlap of the covered areas (e.g., 5% of covered area) to help facilitate track handoff from one sensor station to the next. Each Sensor Station has been designed to be capable of covering a 200 foot long section of roadway with sufficient resolution to track vehicular dynamics.

Tower height: Tower height should be selected in conjunction with setback and separation to provide optimum measurement fidelity. The towers have been selected to accommodate a nominal 100 foot height above the roadway. It is desirable to exploit local terrain relief to gain additional height, if at all possible. In general, a higher tower mitigates obscuration and projects a higher percentage of the sensor imaging area on to the region of interest. The minimum usable tower height is 75 ft., below which eye safety, obscuration and geometry constraints preclude acquiring acceptable data in a safe manner.

Due to the height of the towers and the fact that the tower is not designed to be climbed, the following warning should be posted at the base of each tower at the time of deployment.

WARNING: Never climb tower. The tower structure is not designed to bear the additional weight of a person and may collapse upon itself.

Trailer access: The site should be chosen such that there exists adequate access for the tower trailer to be maneuvered and positioned in the desired location using a vehicle capable of towing over 3000 lbs and handling a tongue weight of up to 800 lbs.

Guys, anchors, and soil composition: The tower locations must be amenable to positioning the required supporting guy wires. The guy wires must have an obstruction-free path from the tower attachment points to the ground. The number and size of the guy wire anchors must be selected based on the soil composition (e.g., sandy soil requires more and larger anchors than clay soil). Refer to Appendix C for guidelines for selecting anchors. It will be necessary to conduct a structural loading analysis and soil load bearing capacity test prior to selecting the number, size and type of anchor. Before anchoring, contact MISSDIG to locate any utility cables in the vicinity.

Security fence: The towers, guys, and enclosures shall be isolated from public access. The site plan shall be amenable to a six foot high security fence encompassing the entire system deployment. Also, there shall be 24-hour surveillance by a security guard with a clear line-of-sight to the site entry and a security system around the periphery of the fence to deny access to unauthorized personnel. Surveillance cameras or intrusion detectors around each sensor station may be employed to aid the security guard.

Scene Fiducials/References: Small objects (i.e., spheres or flat surfaces) coated with retroreflective material should be strategically deployed in the scene. These reference points will be used to perform a bulk registration of the collected imagery. They also will be used to ascertain proper system performance. If the references are not found as expected in the imagery, then the software will detect a failed state and will shut the system down. This acts as an additional interlock to detect a failed scan mechanism. Some of the fiducials should be positioned in regions where two sensor fields-of-view overlap. This will aid in vehicle track handoff.

Survey: The site should be professionally surveyed to determine the exact locations of the towers and the fiducials. Survey data will be input to the track generation algorithms to form a local reference frame.

3.2 Power

Each enclosure shall be provided bi-phase service. The air conditioner and heater are connected to one phase, but will never operate simultaneously. The air conditioner requires 880 Watts continuous line power and the heater requires 500 Watts. The surge current for the air conditioner is 20 Amps. The computer and electronic equipment housed in each enclosure are connected to the other phase of the bi-phase service and require a conservatively estimated 500 Watts. Figure 8 shows a schematic diagram for a three tower deployment using a three phase service drop. The design assumes that power from a public utility will be available. It will be necessary, therefore, to contact the local electrical utility to arrange for an electrical service drop. Power cable hook up to service drop shall be performed by a qualified electrician after obtaining the necessary permits.

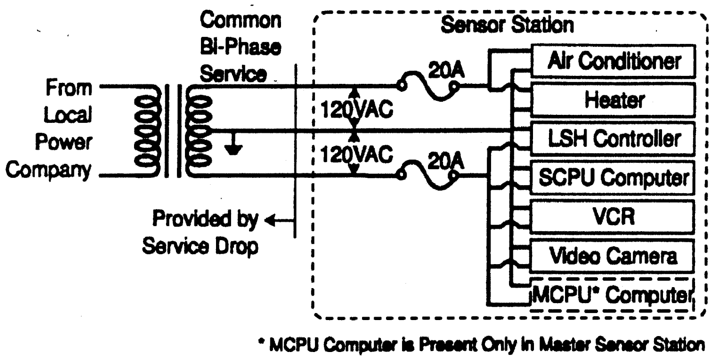


Figure 8. Schematic Diagram of Power Subsystem for a Sensor Station

4.0 Obtaining Approvals

For each deployment site, the site plan should be submitted to the Federal Aviation Administration (FAA) to ensure compliance with regulations on height of structures. Also, approvals and permits at appropriate levels (e.g., state, county, municipality) must be obtained prior to deployment. Consult local authorities to ascertain the necessary approval chain because the process will vary from location to location. Any height and setback variances must be obtained prior to the deployment of the system. This approval process can often be time consuming, so plan ahead and begin the approval process during the early planning stages.

5.0 Deployment and Removal of the VME-MS

It is very important that procedural instructions be closely followed when deploying or removing the VME-MS. This section outlines the procedure to be followed in the deployment and removal of each sensor station. The general procedure is as follows:

1. Identify a location for which to study traffic phenomena. Refer to section 3 of this manual for a discussion of important issues to consider when attempting to optimally cover a site.
2. Contact the FAA about the existence of any height restrictions and file any necessary forms required for approval.
3. Contact the local and state agencies to obtain the necessary approvals and file forms that need to be obtained concerning the site, including any height and setback variances.
4. Perform any soil loading tests necessary to ensure anchor stability.
5. Erect Fencing at the site and Contact a security provider for a security guard and alarm/CCTV system
6. Position and level the trailers in the proper locations.
7. Erect the towers per the manufacturer's instructions, found in Appendix C. Remember to not connect the power to the laser controller until the tower has been deployed to operational height.
8. Scene fiducials/references should be deployed according to considerations found in section 3.
9. Have the site professionally surveyed to determine the exact locations of towers and scene fiducials.
10. Post all required signs and ensure that all warning labels are readily visible at the base of each sensor station.
11. Connect power to the laser controller and ensure proper operation.

Upon completion of the data collection, the towers should be telescoped inward and set on the trailer, again by the manufacturer's instructions found in Appendix C. All Signs, Fencing, etc. erected at the site shall also be removed after the system is removed from the site for storage.

6.0 Operating the VME-MS

After the steps for deploying the VME-MS, outlined in section 5 have been properly accomplished, the system will undergo an initialization process. This process will include a warm-up step to ensure that all equipment has power and a surveying step to locate the scene fiducials with the sensors and establish a site coordinate system. Once the initialization process is complete, the system will be operated in either one of the following two modes: diagnostic and turnkey.

6.1 Operating in Diagnostic Mode

Upon completion of system deployment and initialization, a series of tests will be conducted by trained ERIM staff to assess the proper operation of the system and the quality of the collected data. Some short sequences of vehicular traffic may be collected and analyzed at the site to ensure proper performance. Diagnostic mode is interactive and, upon successful completion, evolves naturally into Turnkey mode.

6.2 Operating in Turnkey Mode

As the name suggests, turnkey mode is carried out with no (or very little) human intervention. Once proper system performance and acceptable data quality has been ensured by the diagnostic tests, the system is left to operate autonomously. On a daily basis, a trained operator should verify the continued operation of the system and should change the data tapes that contain all of the information saved over the previous 24 hour collection time. In addition, he should visually inspect the site, including trailers, guy wires and fence. If the operator notices any condition not discussed in this manual or finds that the system has shut itself down, he should immediately contact the appropriate authority.

6.3 Routine Maintenance

The following routine maintenance should be carried out on an as-needed basis or in compliance with the operation manuals of the corresponding subassemblies.

1. Air Conditioner filter cleaning. The A/C filter should be cleaned regularly to ensure adequate cooling. The frequency of cleaning depends on the environment (e.g., high dirt or dust region will require frequent cleaning).
2. Lubricate the trailer and check trailer tire pressure as described in the trailer operation manual.
3. Charge the tower deployment battery as needed.
4. Clean the data tape drives. Both the DDS and VCR tape drives may need periodic cleaning. Again, the frequency of cleaning is environment dependent. If the VCR is giving a fuzzy or snowy picture, then probably both DDS and VCR tape drives should be cleaned. Since the DDS tape is just storing numbers it is difficult to tell when the tape drive is getting dirty.
5. Laser Sensor window cleaning. The window of the laser sensor should be cleaned regularly to accordance with the Perceptron LASAR Datacamera Operation Manual.

No internal service of the LASAR Datacamera should be performed without explicit approval of Perceptron.

Appendix A

Summary of State Laser Safety Regulations

SUMMARY OF STATE LASER SAFETY REGULATIONS

The following is a listing of the regulations from the various states - this is believed to be current to February 1994. Note that these regulations apply to user installations and service centers, and are not product requirements.

New York State

The New York State Industrial Code 50 requires that each installation be registered, unless the product is exempted or "approved" by the state. Control measures would also apply to the installations which are not exempt. They are in the process of modifying their regulations to consider as "approved" any product that is certified to CDRH Class IIIa or below.

Class I products are normally exempt during operation. Persons doing service on products with embedded Class III or Class IV lasers may need to be registered with the state unless the manuals and procedures specify that the laser be turned off during service. Their address is: Radiological Health Unit, NY State Dept of Labor, 1 Main St., Brooklyn, NY 11201. The contact is Mr. George Kasyk at (718) 797-7642 or -7636.

Texas

Class I installations are exempt from registration and most requirements. Contact the Occupational Health Branch, Texas State Dept of Health, 1100 W. 49th St., Austin TX 78756.

Massachusetts

They are interpreting their 10 year old regulations to apply in the same manner as the SSRL (See below). Their address is: Mass. Dept. of Public Health, 150 Tremont St, Boston MA 02111.

Florida

They have issued registration and control measures requirements which apply to Class III and Class IV products or to Class I products where there is access to those energy levels during service. The contact is James Futch at the Florida Dept of Health and Rehabilitative Services, 1317 Winewood Blvd, Tallahassee, FL 32301, Telephone (904) 487-1004.

Georgia

Their outdated (1971) regulations require registration of all laser products (even Class I). Their plans to update their regulations have been delayed. They apparently have not been taking enforcement action for products below Class IIIb, however, their laws do specify that fines can be levied up to $1000. The address is: Diagnostic Services Unit, 878 Peachtree NE, Suite 719, Atlanta, Georgia 30309, Telephone (404) 894-7623.

Arizona
Their regulations exempt Class I products from registration except for facilities where operation or routine maintenance of products involves access to Class IIIb or Class IV energy. Fees for registration have been imposed starting in January 1994. The contact for these requirements is Bill Pitchford at the Arizona Radiation Regulatory Agency, (602) 255-4845.

Alaska
Controls measures are specified in their 1971 regulations, however, there is no registration requirement. Contact the Alaska Dept. of Health and Social Services, Environmental Health Section, Pouch H-06F, Juneau AK 99811.

Illinois
Their 1968 regulations require registration of all laser products, and although the law includes provisions for fines, there does not appear to be any enforcement activity. Contact the Illinois Dept. of Public Health, Office of Environmental Health, 535 Jefferson St., Springfield IL 62761.

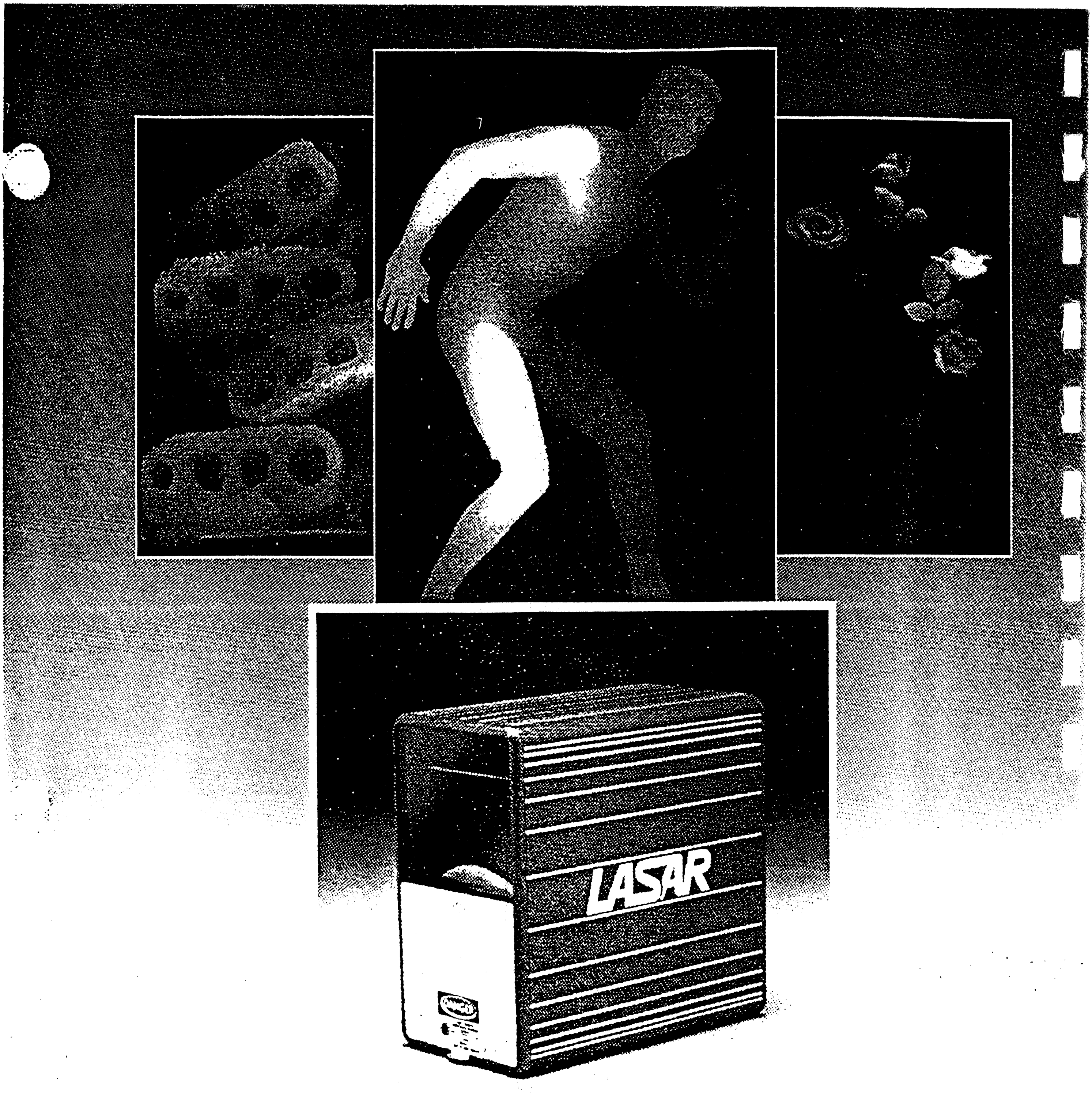
Suggested State Regulations for Lasers (SSRL)
The SSRL is a model set of regulations which was published by a conference of state radiation control officers. The states may individually adopt them if they so choose, or they may adopt an amended version (e.g., Florida and Arizona).

Products other than Class IIIb and Class IV are exempt from registration unless service requires access to energy levels in those classes. Information on the SSRL can be obtained from the Conference of Radiation Control Program Directors, 71 Fountain Place, Frankfort, KY 40601. Tel: (502) 227-4543.

California and Michigan
These states have adopted the OSHA Construction Regulations from the April 17, 1971, Federal Register. They apply only to lasers used on construction sites.

Appendix B

Perceptron LASAR® Datacamera Operation Manual



LASAR®
DATACAMERA
OPERATION
MANUAL

PERCEPTRON

Introduction

Congratulations on your purchase of a Perceptron ***LASAR*** datacamera system! You now own the state-of-the-art in 3D digital imaging technology.

The *LASAR* datacamera provides a means of quickly and accurately generating large field of view, high resolution 3D images. As a result it stands to revolutionize the fields of automated measurement, inspection, and guidance. A rapidly growing list of customers are using the *LASAR* datacamera to solve challenging 3D measurement, inspection, and guidance applications.

The ***LASAR*** datacamera is a scanning laser range finder based on laser radar technology. The datacamera scans a scene with a tightly focused spot of infrared laser light. By measuring the phase shift of reflected signals, it computes the range to the surfaces upon which the light is incident. Your ***LASAR*** can make over 800,000 such range measurements per second. By scanning over a nominal 30° vertical by 50° horizontal field of view using a raster format, it creates high-resolution 3D images of surfaces, objects, and scenes.

General Description

The Perceptron ***LASAR*** datacamera system hardware consists of a scan head, a control module, two VME interface cards, and interconnecting cables.

The scan head contains the scanning mechanism, laser transmitter, detector, and associated optics and electronics. The scanning mechanism consists of a rotating six faceted polygon mirror and a planar nodding mirror (see Chapter 3). The polygon creates scan lines in the vertical direction and the nodding mirror fans them out in the horizontal direction. The result is a raster format scan of the laser beam over a wide field of view.

Scanner

The laser transmitter consists of a solid state laser and collimator assembly, an oscillator, and laser bias amplifier. The laser emits a collimated laser beam of wavelength 935 nm (near-infrared). The transmission optics de-collimates the beam to give a divergence angle of 2.1 milliradians. The oscillator modulates the amplitude of the outgoing laser beam at 10 Mhz. to allow for phase detection-based range measurements The oscillator is adjusted such that the peak to peak current waveform is higher than the dc bias of the oscillator. The result is that the output power is nearly a square wave with a rounded top. The bias amplifier allows for the high power (up to 750 mwatts peak). The average power out of the scanner window is between 260 and 368 mwatts., depending on the particular scanner..

The laser detector consists of receive optics and an avalanche photodiode (APD) detector. The receive optics collect laser energy reflected from the target point upon which the outgoing beam is incident and focus it on the APD. The output of the APD is routed to the control module for processing. The received optical energy is optically filtered with a 4 nm. Wide bandpass filter. The center of the bandpass is adjusted by adjusting the angle of the bandpass filter to the wavelength of the particular laser in each scanner. The bandpass filter, along with the polygon facets forms the receive aperture and creates a receive area of 2100 mm^2. The receive lens has an EFL of 157 mm. and an aperture of 71.5mm. The detector is 0.8mm in diameter. The resulting IFOV is 5 mrad.

Control Module

The control module is a 19" rack mountable enclosure which contains the range measurement electronics, A/D converter, and power supplies. The range measurement electronics detect the phase shift between the transmitted and received laser signals. A calibration EPROM adjusts this range measurement for the effects of varying received signal intensity.

The A/D converter produces a high speed data stream containing both range and intensity measurements. Each word output by the A/D contains 32 bits. There are 12 intensity bits, 12 range bits, and 8 flag bits.

This data is sent from the control module to the 3D Interface card via a RS-422 communication line. Control signals are sent from the Host Computer to the control module via a standard RS-232 communication line.

Interface

The standard ***LASAR*** interface consists of two 6U form factor VME cards. The 3D Interface card acts as a serial to parallel converter. It takes data from the high speed communication line from the control module and writes it to the dual-port RAM card. The RAM card has a standard capacity of 4 MB (expandable to 8 MB) and can hold one pair of 1024 by 1024 pixel range and intensity images. This card is of Motorola design and is described in detail in separate documentation

Specifications

Field of View

Nominal horizontal FOV (programmable)........50°
Nominal vertical FOV_....................................30°
Number of polygon facets................................. 6
Scan lines per image ....1 to 128
Pixels per line..180
Ambiguity interval..15 M.

Physical/Power

Scan head dimensions..................18.5" H X 17"D X 15.25"W (approx.)
Scan head weight .... 65 lb.
Control module dimensions....................19" x 7" x 24"
Control module weight ....25 lb.
Cabling between head/module ....110 feet
Input voltage .... 115 VAC 10 amps
Max. Operating temperature.............................90° F.(no solar heat load)
Max. Storage temperature................................110° F.

Laser / Optics

Laser type .... Solid state
Laser output power (avg)...........ERIM001 368 mW.
ERIM002 TBD mW.
ERIM003 360 mW.
Laser wavelength ....935 nm.
Spot size leaving scan head............................3 mm.
Beam divergence..2.1 mrad.
Receiver collecting area...............................2100 $mm.^2$
Receive lens focal length.............................157 mm.
Detector diameter...0.8 mm.
Receiver IFOV..5 mrad.
Polygon scan speed................................13,750 rpm.

Data

Intensity resolution .... 12 bits
Range resolution .... 12 bits
Pixel rate ....843,750 Hz
Image acquisition up to.................................10 frames/sec.
Data Storage ....Dual-port RAM
Storage Capacity ....4 MB
Bus compatibility ....VME

Laser Safety

It is recommended that all persons who are in the vicinity of lasers be aware of the potential hazards. Use of controls or adjustments or performance of procedures other than those specified in this document may result in hazardous laser light exposure.

NOTE: **The use of optical instruments with this product may increase eye hazard.**

The laser source of the ***LASAR*** datacamera is a 750 mW laser operating at a wavelength of 935 nm. This system meets CDRH safety requirements and is registered with CDRH. Under normal operation the laser has an average power of 360 mW.

Safety Interlocks

Several safety interlocks are built into the ***LASAR*** data camera. There is a polygon speed interlock which will turn the laser off if the polygon is not near it's programmed speed. A remote interlock connector is provided on the controller that will allow the user to turn off the laser when a protected area is entered. The remote interlock is intended to be connected to a power free normally open contact. The contact being held closed indicates a condition that allows the laser to be on.

NOTE: **Opening the remote interlock connection turns off the laser.**

A keylock, removable in the off position only, is provided on the controller enclosure. This keylock is used to remove power to the laser. An amber laser power indicator on the scanner head and a green led indicator on the card cage indicate the status of the laser power. These indicators are on when the laser is emitting and will be on 10 seconds prior to the start of laser emission. The scanner head enclosure is interlocked. If the cover is removed, power to the laser will be removed. Normally a permanently attached mechanical means of blocking the laser beam would be mounted on the scanner. In this application, since the scanner, in normal use, is at the top of a 100' tower and is not accessible, the beam blocker has not been implemented.

It is imperative that the following cautions be strictly observed.
1. Never look directly into the laser beam.

2. Controlled access areas are suggested for laser operation. Limit access to this area to those who have been instructed in the safe operation of lasers.

3. Post caution signs in prominent locations near the laser use areas.

4. Whenever directly working on a Class IIIb device, first turn the Laser Power Key Switch to the "OFF" position.

For Regulations and Requirements:
Director
Office of Compliance
Center of Devices and Radiological Health
(FDA/CDRH)
8757 Georgia Avenue
Silver Springs, Maryland 20910

For Safety Guidelines:
American National Standards Institute, Inc.
1430 Broadway
New York, New York 10018

Maintenance

The only required routine maintenance is to clean the scanner window as required. When cleaning the window, turn the Laser Power Key Switch to the "OFF" position. Using a lint free cloth and commercial window cleaner, spray the cleaner onto the cloth, then wipe the scanner window. After this procedure is complete, turn the Laser Power Key Switch back to the "ON" position and verify operation of the Emission Indicator by ensuring that it is illuminated.

NOTE: NEVER spray commercial cleaner directly onto the scanner window.

Make sure that the power is OFF while connecting cables.

Scanner Interface and Control

The ***LASAR*** scan head is controlled by the host computer via an RS232 interface. A nine pin DB serial port is located on the rear panel of the control module for this interface. There are three signals used to implement the interface: transmit, receive, and Clear to Send (CTS).

DB9 serial connections

Pin 1	n.c.
2	RxD
3	TxD
4	n.c.
5	GND
6	n.c
7	n.c
8	CTS
9	n.c

The control module listens to the serial port only when the system is not scanning. If a command is transmitted from the host while the system is scanning, the command will be ignored.

If the scan head is busy CTS is not asserted. When it completes an operation it will assert CTS for about 10 μsec. and then remove it. This should be enough time for the host to start sending a character. This character will be buffered and processed before the CTS line is asserted again to receive the rest of the command.

3D Interface

The 3D interface consists of two 6U form factor VME cards. The 3D Interface card is a proprietary design and acts as a serial to parallel converter. It takes data from the high speed communication line from the control module and writes it to the dual-port RAM card via the P2 connector. The P2 of both the memory and 3D interface must be connected via the 64 conductor ribbon cable provided. The RAM card has a capacity of 4 MB. This card is of Motorola design and is described in detail in separate documentation.

Each pixel of the image uses 4 bytes of memory. Therefore, any image format whose row by column product is less than 1,048,576 can be accommodated by the interface. The serial to parallel converter card can generate test data which can be used to verify operation of the interface. It still requires line sync from the scan head to operate in the test mode.

Memory Card

The memory card is a Motorola 4 MB, dual-port RAM card. This card is shipped from Perceptron with the VME access at addresses $400000 through $7FFFFF. This address range may be altered to suit your own system needs. The VSB address range of memory starts at address location 0. **This address must not be changed.**

3D Interface Card

The 3D interface card receives the serial data stream from the scan head and converts it to a form that can be written into the memory card via a private VSB bus. In addition , the interface provides registers which can be used to qualify the data from individual pixels as well as control the operation of the 3D interface.

Greater than(GT)/Less than(LT) Registers

Pixels which have a very high or very low intensity may contain data which is unreliable. Two 16 bit registers, GT (greater than) and LT (less than), are provided.
Two 16 bit registers are provided to indicate to the VME CPU if the 3D interface is busy and provides the upper 8 bits of the address currently being used. This feature allows for data to be removed from the memory before a scan is complete without getting ahead of the scan.

The interface controller is accessible on the VME bus in word format only and is addressed from $900000 through $90003E. All registers are write only. To set the registers enter a 1 (one). To clear the registers enter a 0 (zero).

Four registers are an exception to this rule.
They are as follows:

GT / LT Value	**Write Only, 16 Bits**
Stop Address Low 4	**Write Only, 16 Bits (Low 4 used)**
Stop Address High 4	**Write Only, 16 Bits**
Status Register	**Read Only, 16 Bits**

Register Map

The 3D interface registers are located as follows:

Address	Register
$900000	Frame Request
$900002	Test Frame Request
$900004	Not Test
$900006	Ack. Reset
$900008	Address Reset
$90000A	Status Bit 0
$90000C	Greater Than Enable
$90000E	Less Than Enable
$900010	GT / LT Value
$900012	Stop Address Low 4
$900014	Stop Address High 4
$900016	Status Register
$900018 THRU $90001E	Unused
$900020	Intensity Test Data 0
$900022	Intensity Test Data 1
$900024	Intensity Test Data 2
$900026	Intensity Test Data 3
$900028	Intensity Test Data 4
$90002A	Intensity Test Data 5
$90002C	Intensity Test Data 6
$90002E	Intensity Test Data 7
$900030	Intensity Test Data 8
$900032	Intensity Test Data 9
$900034	Intensity Test Data 10
$900036	Intensity Test Data 11
$900038	Busy Reset
$90003A THRU $90003E	Unused

Register Description

Frame Request

When the Frame Request is set to an odd number, the interface will begin storing data from the scan head into memory when it receives the next frame sync signal. After a Frame Sync is received by the 3D interface, a frame busy bit will go active. After this condition is sensed the Frame Request must be cleared before the next frame sync.

Test Frame Request

When the Test Frame Request Register is set to an odd number, the memory card range data will be filled with an incrementing range pattern, and the intensity pattern set by the Test Data 0 through 11 data bits. Data generated by the scan head will not be used. A block of test data (256 or 1024 pixels, typical) is clocked in by the line sync pulse. Data collection terminates when the number of pixels collected exceeds the STOP ADDRESS.

Not Test

This register must be set to select the source of data that will be written into memory.

Register Contents	Source
Even	Test Data
Odd	Sensor Data

Ack Reset

This register is used to set the 3D interface to a known state. It is an active high reset for the VSB "ACKNOWLEDGE" signal. This must be done on power up and optionally used to recover from error conditions.

Address Reset

This register is used to reset the memory address counters. The counters must be reset prior to gathering data. Writing an even number to the register followed by an odd number, will clear the counters. In order to enter two or more consecutive frames (or partial frames) into memory, do not clear the counters after the first frame is received. This ensures that the next frame will be loaded into memory starting with the address following the last address of the previous frame.

Status Bit.

The Status Bit is available for use by the host computer. It is not defined for use by the LASAR system.

Greater than Enable

Writing an even number into this register will enable the greater than status bit.

Less than Enable

Writing an even number into this register will enable the less than status bit.

GT/LT Value

This is a 16 bit register that stores values for the Less thanl/Greater thanl compare function. Eight bits for each of the upper and lower thresholds are provided. The lower threshold is the low order byte of the VME word and the upper threshold is the upper byte of the VME word.

The 8 MSB of the 12 bit intensity is compared to the Lower Threshold. The LT bit is set if less than the threshold. The 8 MSB of the 12 bit intensity is compared to the Upper Threshold. The GT bit is set if greater than the threshold.

$d > GT \quad 1$ or $GT > d \quad 0$

The register contents are defined as follows:

Bits	Function
D0 - D7__	8 Bit Lower Threshold
D8 - D15	8 Bit Upper Threshold

Stop Address

The number of pixels taken in any scan is programmable, even though the number of pixels per scan line is fixed. The nodding mirror motion may be programmed to give any angular excursion from 0° to 50°. The speed of rotation of the nodding mirror may also be programmed so that fewer or more lines may be generated in a given amount of rotation. This can be used to reduce the amount of data that has to be analyzed, reduce the scan timer or increase the resolution of the data in the nodding mirror axis. To complement this programmability the 3D interface contains two stop address registers. These registers should contain the product of the number of pixels per line and the number of lines.

Stop Address Low 4

This 16 bit register uses its lower 4 bits to define scan stop address bits SA0-SA3.

Stop Address High 16

This 16 bit register contains the upper 16 bits of the stop address SA4-SA19.

Status Register

This is a 16 bit read only register. Its contents are as follows:

Bit	Function
0	Sensor Frame Busy (active high)
1	Test Frame Busy (active high)
2	Laser Power (High Indicator On)
3-6	Unused
8-15	Upper 8 bits of address currently being used

Since it could take several seconds to acquire a complete frame, the 3D interface provides the current address block being written to so that processing of the data already acquired can begin ahead of frame completion. The address can be interpreted as follows: Address less than (Upper Byte of Status) x $4000 are available for processing.

Data Format

Data written into the memory card by the 3D interface may come from either the scan head or the card test function. In both the Test and Sensor Modes, the memory is not written to in the first long word. The first pixel is at offset 4 from the VME base address, the second is at offset 8 etc.

Sensor Data Format

Sensor data is defined as follows:

BIT	FUNCTION
0-11	Range Data 0-11
12	SD0
13	SD1
14	SD2
15	SD3
16-27	Intensity Data 0-11
28-31	Unused (Always 0)

Test Data Format

The test data is written into the memory in the following format:

BIT	FUNCTION
0-19	Address 0-19
20-31	Test Data 0-11

Data bits 0-19 are tied to the address currently being written to. At the end of a test frame the memory should contain the addresses and test data bits previously set up by the host computer.

Compare

If enabled, the compare functions set the SD# flags if the Upper Threshold is exceeded or if the Lower Threshold is not exceeded The GT (greater than) and LT (less than) bits are programmed as follows:

GT	LT	FUNCTION
0	0	Neither
0	1	Less than Only
1	0	Greater than

The results of the comparison set the SD 0-3 bits active high as follows:

BIT	FUNCTION
SD0	Set by the user if desired.
SD1	Less than
SD2	Greater than
SD3	Less than or Greater than (if enabled)

SCAN CONFIGURATION AND PROGRAMMING

The ***LASAR*** datacamera scans a tightly focused laser beam over its field of view using two mirrors. One is a high speed, rotating polygon mirror and the other is a nodding, galvanometer-driven, planar mirror. The polygon creates vertical scan lines at high rates. The nodding mirror moves these scan lines in the horizontal direction, creating a raster-format scan of the entire field of view.

The polygon has six facets, each of which creates one scan line as it is rotated across the transmitted laser beam. Therefore, six scan lines are created during each revolution of the polygon. When the polygon is rotating at 13,750 RPM, the scan line rate is 13,750/60 x 6 = 1375 Hz.

A constant number of pixels are digitized along each scan line. However, the spatial resolution may be adjusted by selecting the polygon speed to one of two settings—normal and 2X zoom. Decreasing the polygon speed has the effect of decreasing the horizontal field of view and increasing the spatial resolution along the scan lines.

The nodding mirror is a planar mirror driven by a galvanometer. When the nodding mirror steps it moves the scan lines in the vertical direction. The step size and number of steps per frame are programmable.

Scan Parameter File Commands

List Presently Active Scan Parameters ?(cr)

This command causes the presently active scan parameters to be transmitted to the host via the serial port.

Store Scanned Program Number Fx(cr)

This routine stores a program number from 0 to 9, which stores the current scan parameters in a list for later viewing. This data is stored in volatile memory.

Retrieve Requested Parameter List Rx(cr)

This routine retrieves a program number from 0 to 9. The retrieved parameters will replace the currently active list.

Programming the Nodding Mirror

Initial Position Ixxxxx(cr)

The initial position is the nodding position at which the scan will start. Valid values for Ixxxxx are between 0 and 65535. Upon issuing this command the mirror will immediately move to the initial position.

End Position Exxxxx(cr)

The end position is the nodding mirror position at which the mirror stops. Valid values for Exxxxx are between 0 and 65535. The end position value may be larger or smaller than the initial position, allowing the scan to go in either direction.

Step Size Sxxx(cr)

The step size is the value that will be added to (or subtracted from) the nodding mirror's present value for each incremental position that creates the scanning motion of the nodding mirror. This position will be incremented until the end position is reached. Valid values for Sxxx are from 1 to 200.

Step Delay Dxxx(cr)

Step delay or step period is the time delay between incremental mirror position commands step size during the scan. There is a minimum delay of 60 microseconds. The resolution is in increments of 10 microseconds above the minimum fixed delay of 60 microseconds. Valid values for Dxxx are from 7 to 200. The formula used is
(D-6) x 10 = microseconds/step.

For example, a value of 10 will give a delay of
(10-6) X 10 = 40 microseconds/step.

Scan Control Commands

Bi-directional Scan B(cr)

In this mode, the nodding mirror continuously scans from the initial position to the end position, and vice versa.

A frame sync (start of frame) is initiated in each direction. The host system is responsible for interpreting the orientation of the image. This command is terminated by sending a character on the RS232 line

Take a Scan X(cr)

This command causes the scanner to take one image. The nodding mirror moves from the initial position to end position with the velocity as programmed by the step size and step delay. The nodding mirror will then remain at the end position until a new X command is received. When a new X command is received the nodding mirror will move form the old end position (now the new initial position) to it's original position (now the new end position). Please note that the alternate images will be mirror images.

Take a Scan GO(cr)

This command causes the scanner to take a single scan starting at the initial position and ending at the end position. The nodding mirror then retraces to the initial position.

Retrace Step Size Vxxx(cr)

The retrace step size determines the step size during retrace. The higher the number, the higher the retrace velocity. If it is too high, then in retrace the mirror may overshoot and slap the mechanical stops. This could result in the mirror mounting screws loosening over time.

NOTE: **This parameter is not saved by the "F" command.**

There is some trial and error involved in determining the final values for step size and step delay that give the desired image size and resolution.

The first task is to determine where the start and end positions of the scan will be. We have determined **approximate** values to give a 50 degree scan for each of the three scanners purchased. The values are as follows:

	Initial position	End position	Step Size	Delay
ERIM001	2000	63500	50	10
ERIM002	5000	61500	50	10
ERIM003	2000	63500	50	10

NOTE: We strongly recommend the use of laser safety glasses when performing these procedures.

NOTE: <u>Never</u> try to get in the field of view and look back into the scanner to see where the scan line is.

The parameters may be fine tuned from this starting point. If the nodding mirror must be sped up then the step size may be increased and/or the step delay decreased. Altering the maximum field of view from those given above may caused the nodding mirror to hit the mechanical stops and to cause erratic operation and servo loop oscillation.

Scan Continuously C(cr)

This routine causes the galvanometer to scan repeatedly until the processor receives a hardware reset or receives a character on the serial line. The subroutine immediately executes one scan, waits one second, then repeats the cycle.

Execute One Scan T(cr)

With this command the galvanometer immediately executes one scan. **NOTE. In this mode the nodding mirror is not synchronized to the polygon.**

Programming the Polygon

The polygon speed can be altered via the "/x" command. For full speed x is set to 1. If no frames are to be taken for a while but you want to keep the polygon spinning then sending a "/2" command will reduce the polygon speed to 1/2. By sending a "/4" command, the polygon will be stopped. The laser will be shut off by the polygon speed interlock when this is done.

Start of Scan Offset Ox(cr)

This command sets a start of scan offset. The range of valid numbers is 0, 1 and 2 when the polygon speed is at the '/2' setting. The only valid offset at the full speed, /1, is O0. Assuming that the speed is set to half speed then selecting O1 will cause the scanner to image the left 15 degrees of the full 30 degree FOV. With O2 selected the center 15 degrees of the field of view is imaged and with the O3, the right 15 degrees of the FOV is imaged.

Appendix C

Trailer/Tower/Anchor Operation Manual

ALUMA TOWERS

Installation Instructions

ALUMA TOWER COMPANY, INC.

TOWERS FOR COMMUNICATIONS

1639 OLD DIXIE HIGHWAY
BOX 2806
VERO BEACH, FLORIDA 32961-2806
(407) 567-3423 TELEX 80-3405
FAX 407-567-3432

ALUMA TOWERS

INSTALLATION INSTRUCTIONS

IMPORTANT NOTE: WARNING. INSTALLATION OF THIS PRODUCT NEAR POWER LINES IS DANGEROUS. FOR YOUR SAFETY, FOLLOW THE INSTALLATION DIRECTIONS.

TOWER SITE SELECTION: When selecting the site for your tower, the most important factor to consider is "ELECTRICAL SAFETY". If the tower should come in contact with any electrical wires, you could be KILLED. A good rule of thumb is to measure the total extended height of the tower and mast and locate your tower TWICE the distance from the closest power line. To protect your house and your electronic gear, the mast/tower and antenna system must be properly grounded. Drive a 4' - 8' ground as close as possible to the tower. Then connect a #8 (or larger) copper or aluminum wire between the base of the antenna and the ground rod. Also, a static discharge unit (sometimes referred to as a lightning arrester) should be connected to the antenna lead-in at the place where it enters the home. (Follow the instructions provided with the static discharge unit.) For further grounding and lightning protection information, see below.

ALUMA TOWERS are supplied with two types of bases. One is an aluminum plate attached to the bottom of the tower and drilled with a 1" hole to accommodate the ground spike which is shipped in the end of the mast at the top of the tower. This ground spike will stabilize the base even in sand and prevent side movement of the base of the tower.

The second type of base is hinged with aluminum fittings and is designed for bolting to a concrete pad. A small piece of aluminum angle is attached to the third tower leg for anchoring and support.

The concrete pad should be large enough (heavy enough) to remain stationary when tilting tower to a horizontal position.

It is not necessary to guy two-section towers that are house bracketed. If towers are not house bracketed, they must be guyed at the top of each section. For normal installation of the 30 or 40 foot tower, attach to the building using the "A" or "V" bracket supplied with the tower. Be certain to use at least 2" long lag screws and try to place at least one in the end of a roof rafter.

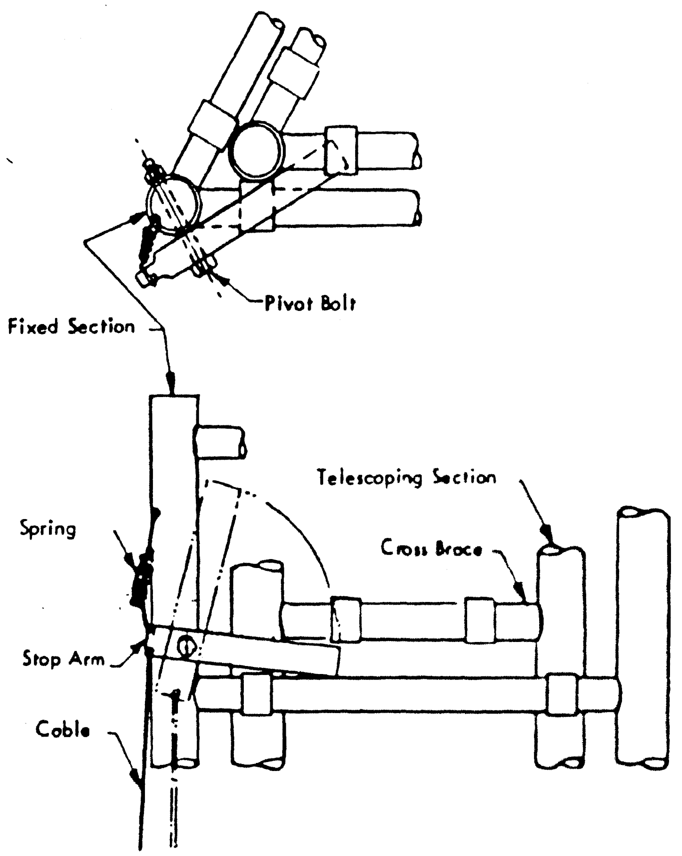
To simplify installation of a tower to be attached to a building, we suggest that the tower be leaned at an angle, roof to ground, so that by standing on the roof you can attach the antenna, stand offs, and lead in wire. Then simply pull and lift the tower into the vertical position, again being sure to stay clear of all power lines, and mount in the pre-positioned two piece bracket. Finally, align tower and stabilize base.

Towers above 50 feet tall (2 sections) must be guyed. If the first 20' - 25' section is attached to the building, the first set of guy wires may be located at the forty foot mark and then at the top of uppermost section in the 60 foot tower. The 60, 75, and 100 foot tower (3 and 4 sections) must be guyed at the the top of each 20 foot or 25 foot section.

The #T-140 tower is not designed for beam type antennas. Do not suggest use with other than small TV type rotor. (Mast supplied with #T-140 is thin wall. Other masts available in medium and heavy duty wall.)

Straight stacked sections of tower to 100 feet tall must be guyed at each 20 foot mark. Note that in all guyed towers it is important that anchor points be located accurately 120 degrees apart and 2/3 of the extreme height of the tower (i.e. 60 foot tower 40 feet from base of tower). It is also important that the guy wires from each leg come off straight in relation to the opposite flat side in order to prevent twisting the tower.

IMPORTANT NOTE: WARNING. INSTALLATION OF THIS PRODUCT NEAR POWER LINES IS DANGEROUS. FOR YOUR SAFETY, FOLLOW THE INSTALLATION DIRECTIONS.



INSTALLATION
OF
ALUMA TOWER
SAFETY STOP

On receipt of Tower, the stop arm, cable, spring and bolt will be found taped to Tower leg (at pivot hole).

Assemble as shown; stop arm to Tower with 1/4" bolt and Esna locknut -- arm must be able to move freely.

When cranking up Tower, the telescoping section will pass by the stop arm. When desired height is reached, lower telescoping section slightly until it rests on stop arm.

Stop arm now will be between a cross bar on the telescoping section and a cross bar of the Tower fixed section (as shown in drawing to left). This will prevent the telescoping section on your Tower from coming down accidently.

To lower Tower, crank up Tower slightly until stop arm is free. Pull down on cable, thereby pivoting stop arm clear of Tower. Crank Tower down.

ALUMA TOWER COMPANY, INC.
TOWERS FOR COMMUNICATIONS

1639 OLD DIXIE HIGHWAY
BOX 2806
VERO BEACH, FLORIDA 32961-2806
(407) 567-3423
FAX 407-567-3432

ALUMA TOWER COMPANY, INC.

MANUAL

Model TM-51-35/T-100
Serial #146AT8355RMF29136

INSTRUCTIONS FOR ASSEMBLING KNOCK-DOWN
TRAILER #TM51-20 & TRAILER #TM51-35

1. Set trailer on level ground and adjust nose jack to level trailer.

2. Mount rear tower superstructure (A) in "U" bracket (B) and secure with 1/2"-3 1/2 Hex Head Cap Screws and ESNA Nuts.

3. Bolt two 81" aluminum pipe supports (C) from top of superstructure forward to black bolts mounted on trailer frame (D). Secure with 3/8"-16 x 1 1/2" Hex Head Cap Screws and ESNA Nuts.

4. Mount front frame (E) in forward frame angle brackets with 3/8"-16x1 1/2" Hex Head Cap Screws and ESNA Nuts.

5. Bolt one aluminum pipe support 78" (F) to upper front frame and to angle bracket (G) with 3/8"-16 x1 1/2" Hex Head Cap Screws and ESNA Nuts.

6. Mount aluminum crank-up tower to rear superstructure using ears on tower and ears provided on superstructure using 1/2-13 x 2 1/2" Hex Head Cap Screws and ESNA Nuts.

7. Release ratchet on tower tilting winch already mounted on rear of superstructure and pull cable from pulley and attach to plate provided on tower (H) with hardware supplied.

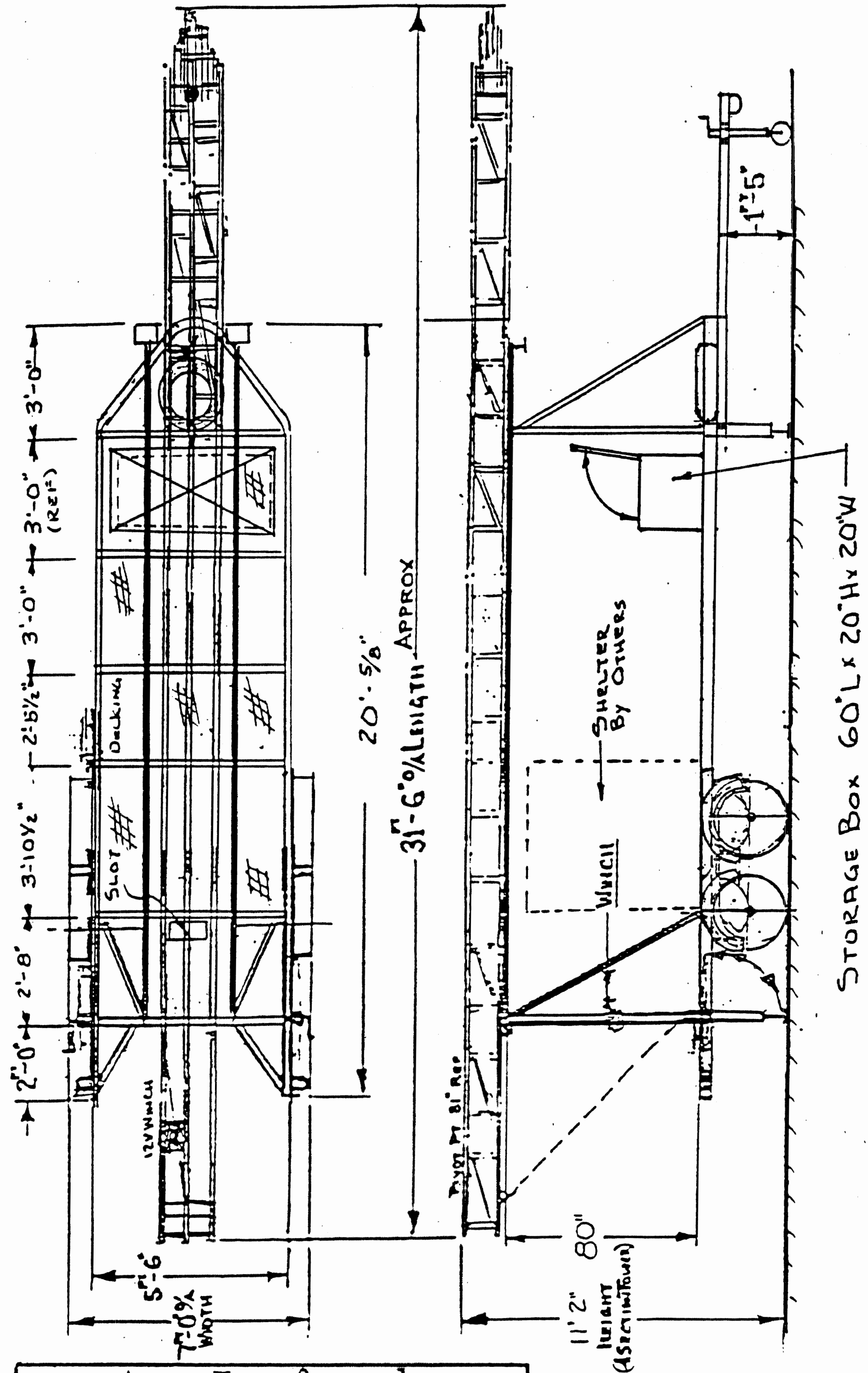
8. Secure safety chain over tower at forward support frame.

9. Mount two 13' galvanized steel stabilizer arms to rear of superstructure with 5/8"-11 x 2" Hex Head Cap Screws and ESNA Nuts.

10. Stow stabilizer arms in forward brackets and contain with ball lock detent pins. Bolt on and install with optional equipment ordered.

Note: Due to different shipping requirements, rear superstructure and/or front A-frame may be already attached to trailer and folded over.

REFER TO ACCOMPANYING SKETCH ON PAGE 2 FOR NOTATIONS (A) THROUGH (H).



ALUMA TOWER COMPANY INC
VERO BEACH FL 32960

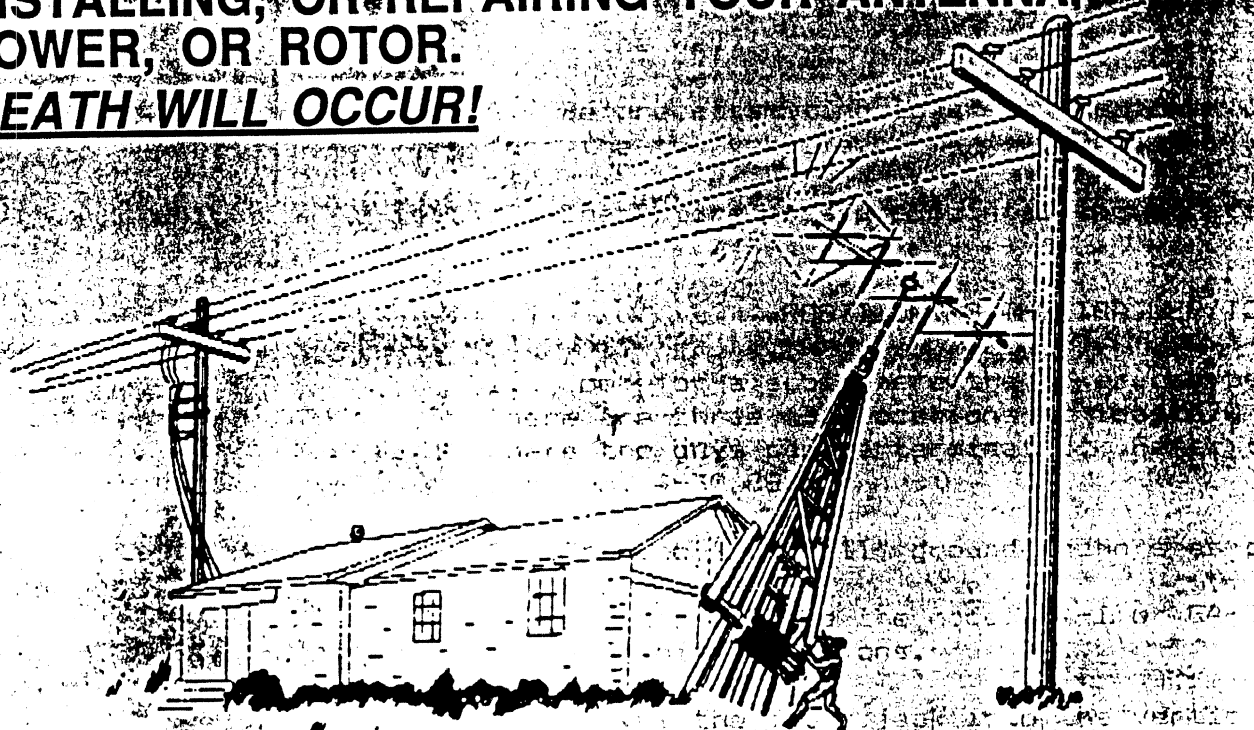
DATE 3-23-94	DR. FRB	SCALE
TOWER TRAILER	TM51-L-35 W/SPECIAL T100 TOWER (4 x 30" SECTIONS B, C, D & E) STORAGE BOX 20H x 20W x 60LG	
	AT-638	

WARNING NOTICE DANGER!!!

CAUTION:

TAKE CARE TO AVOID ANY CONTACT WITH OVERHEAD POWERLINES WHEN RAISING, INSTALLING, OR REPAIRING YOUR ANTENNA, TOWER, OR ROTOR.

DEATH WILL OCCUR!



Installing and rigging towers, masts and antennas require specialized skills and experience. Information supplied by the Company assumes that all products will be installed by personnel having these skills and have installed similar products before. No one should attempt to install towers or masts without these knowledgeable skills.

The Company assumes no liability if faulty or dangerous installation practices are used. There are available, trained, and experienced personnel to assist in installation, maintenance, or disassembly. Contact your local installer if consultation or assistance is required.

All tower and antenna installations should be thoroughly inspected at least twice a year by qualified, experienced, and trained personnel to insure proper performance and safety standards.

ELECTRICAL WARNING

An additional warning precaution is given to be careful of surrounding high voltage power wires, and other electrical hazards during the installation of your tower, rotor or antenna.

Do not erect an antenna tower or rotor during an electrical storm, rainstorm, or when lightning is a possibility.

SET-UP INSTRUCTION FOR TRAILER TOWER

CAUTIONS AND WARNINGS

NEVER set up the tower within 120 feet of a power line.

NEVER tow the trailer with the rear jacks in place they will scrape the ground and be destroyed. Remove them and stow on rear frame. After hooking up the trailer raise the front swivel all the way and swing it out of the way.

A. Before attempting to erect the tower unhook the trailer from the tow vehicle.

B. Check tire pressure maintaining a recommended 30-34 PSI.

POSITIONING THE TRAILER/TOWER

1. Look for a spot where the tower can be placed so that there are three (3) locations at least 70 feet from the tower where the guys can be terminated. Refer to guying lay out Dwg. No. 4-30 CG.

2. Set the "Duckbill" ground anchors as per the instructions

3. As an alternate the model GA-1 or GA-2 can be used in certain soil conditions.

4. Swivel the front jack into the vertical position and crank it down so you can remove the trailer from the tow vehicle. Install the four jacks and level the trailer using these jacks and the leveling bubble on the rear support. Be sure to start by raising the rear of the trailer so that trailer wheels are no longer touching the ground.

5. Remove the two detent pins that hold the "outriggers" in place and carefully lower them to the ground. Next place them on or near the ground and walk the outriggers in an arc toward the rear of the trailer. Be sure they swivel smoothly and do not put undue pressure on the joint. When in place the two "outriggers" should have 120 degree angle between them.

6. Loosen the turnbuckle on the cable attached to the outrigger, unhook the cable and reattach it to the eye at the rear of the trailer. Move the outrigger from side to side until the cable tightens, if necessary tighten the turnbuckle, being careful not to over tighten.

ATTACHING ANTENNA, COAX AND GUY WIRES

1. Feed the coax cable through the middle of the smallest section and on up through the mast at the top of the tower.

2. Loosen the two U-Bolts that hold the mast in place and slide it up so that approximately 18" is still in the tower. Tighten the U-Bolts (do not over tighten).

3. Install your antenna and make the coax connections.

4. Make up guy kit by:
   a. cutting wire to length per Dwg. No. 4-30 CG
   b. assembly turnbuckle per Dwg. No. 4-30 CG
   c. attach guy wires to the tower
   d. longest wire attaches to the top of smallest section, then the rest in descending order, to the lowest section.

5. Make up guy kit for Dwg. No. BCD-699
   a. cut 3 lengths of wire to 150 ft. each
   b. make up turnbuckle assembly per Dwg. No. 4-30 CG
   c. attach to guy ears shown on Dwg. BCD-699

ERECTING THE TOWER

1. Loosen the hold down restraining strap that holds the tower in place in the horizontal mode.

2. Using the hand winch on the rear support crank the tower from the horizontal to the vertical position.

3. Lock tower in the vertical position with detent pins - (thru support frame and tower lugs).

4. Neatly lay out the three lower guy wires and attach them to the ground anchors. Tighten only the lowest set of guy wires. Recheck the bubble to be sure the trailer is still level, if is not readjust the guys until it is.

5. Undo the red safety strap from the bottom of the tower and remove it from the inner sections.

CAUTION - - in Windy Conditions There Must Be Someone at Each of the Guy Wires to Insure That The Wires Are Kept Taut.

6. Raise the tower to the desired height. Remember that the electric winch is capable of damaging the tower, so be alert to any unusual noises. Do not try to over extend the tower.

7. Snug the remaining guy wires by starting at the lower set, be sure that as you tighten the wire you are not pulling the tower out of alignment.

LOWERING THE TOWER

1. Raise the tower slightly to allow you to swing the safety stop out of the way.

2. Lower the tower to the retracted position and attach the red safety strap.

3. Loosen all guy wires.

4. Remove the two detent pins (thru tower lugs and frame) push the tower away while loosening the winch.

5. Lower the tower to the horizontal position and secure the tower with the hold down strap.

6. Return the outriggers to their stowed position and install the safety pin. Be sure the turnbuckles are tight and secured.

7. Raise the leveling jacks and remove the ones at rear and place them in stowed position on frame.

8. You are now ready to hook up the trailer to the tow vehicle. Once again recheck all securing straps and safety wires.

Hopkins Manufacturing Corporation

428 Peyton • Emporia, Kansas 66801-1157 • 316-342-7320

320-9-715

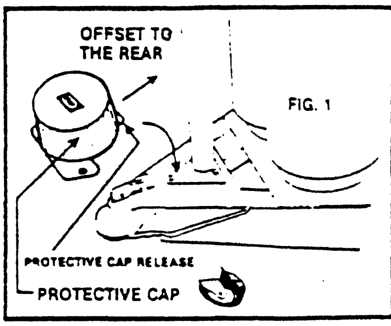
Printed in U.S.A.

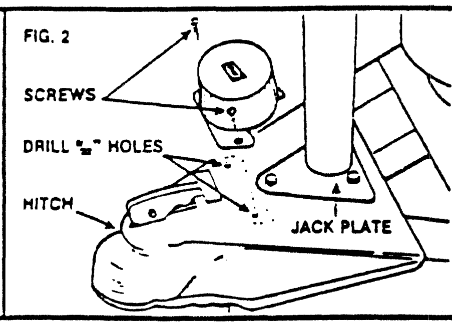
MADE IN U.S.A.

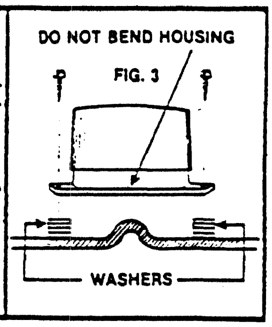
PATENTED

INSTALLATION:

1. Place the hitch level on the trailer tongue as shown. Normally it will be located between the hitch and the jack plate (Fig. 1).
2. The **offset must point to the rear** (Fig. 1) as it provides clearance for the jack plate and its attaching bolts. Transfer the location of the two mounting holes to the mounting surface. Center, punch, and drill 5/32" holes at these locations (Fig. 2).
3. Attach the level with the two screws provided. If the surface is not level, shim the unit with flat washers so the hitch level housing will not be bent (Fig. 3).

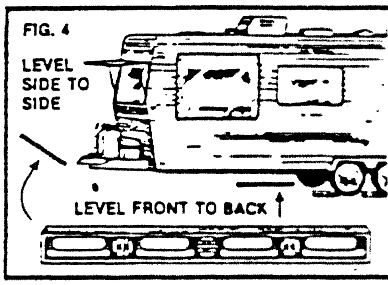


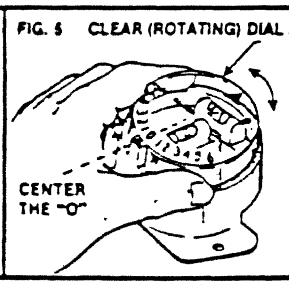


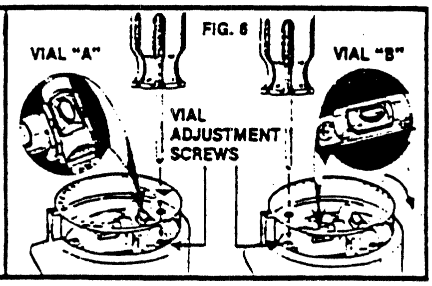


CALIBRATION:

1. Level the trailer (side to side and front to rear) using a carpenter's level (Fig. 4).
2. Turn the clear dial so the "O" is centered on the small black arrow on the gray housing. The large arrow will be pointed to the rear of the trailer (Fig. 5).
3. Turn the adjusting screw under the hole in the clear cover until the bubble is centered in the vial controlled by this screw (Fig. 6). When this is accomplished, turn the cover until the hole is over the second screw and repeat calibration (Fig. 6).

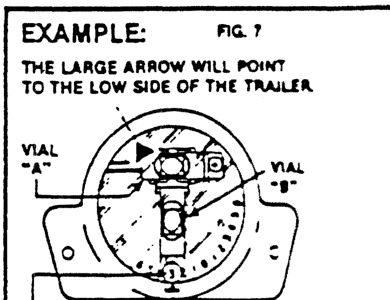


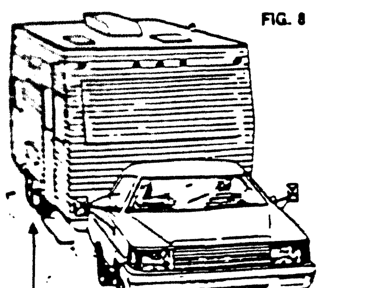


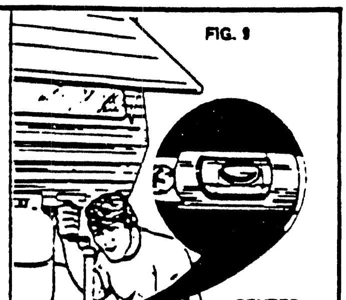


USE:

1. To level the trailer using the hitch level, **leave the trailer hitched to the towing vehicle,** and turn the clear dial left or right until the bubble in vial "A" is centered (Fig. 7).
2. **The number at the stationary pointer is the height in inches** necessary to level the trailer from side to side. **The large arrow on the rotating dial will point to the side requiring elevation.** Pull the trailer onto the leveling blocks (Fig. 8) and chock the wheels so it will not roll.
3. Turn the dial to zero. If the bubble in vial "A" is close to center, proceed to step 4.
4. Unhitch the trailer from the towing vehicle and elevate or lower the trailer with the tongue jack until the bubble in vial "B" is centered (Fig. 9).







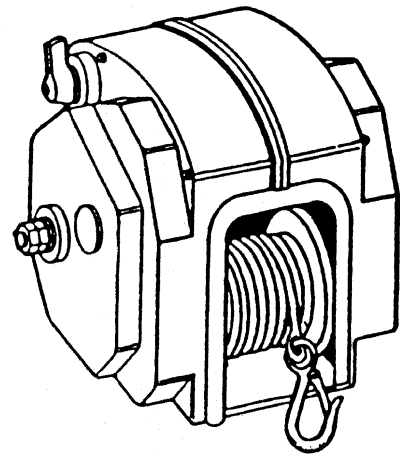
Powerwinch

OWNER'S MANUAL

ELECTRIC WINCH

BH12

SH12HBM



P70361 3/93

READ ENTIRE INSTRUCTIONS BEFORE STARTING INSTALLATION. FOLLOW ALL CAUTIONS, WARNINGS AND NOTES TO PREVENT INJURY OR DAMAGE TO SELF OR WINCH.

WARNING: Always unplug the wiring harness to prevent accidental starting when setting up, adjusting, or making repairs to your winch.

BE SAFE

A. DO NOT allow people who are not familiar with the safety rules use your winch.

B. NEVER use your winch to lift or move people or animals.

C. STAND AWAY from unit when in use and never use for overhead lifting.

D. ALWAYS keep hands clear of cable spool (drum area).

E. Keep the winching area FREE OF CHILDREN. Only let adults use your winch.

F. ALWAYS wire your winch with the circuit breakers. Failure to use the breakers could cause over-heating—creating the potential for fire.

G. ALWAYS stand clear of the area between the load (or anchoring point) and your winch. Should the cable snap and you are within the winching area, you could be seriously hurt.

H. INSPECT the entire CABLE before use to check for fraying (wear by rubbing) or kinking (short tight twist or curl).

I. When replacing the cable, ALWAYS replace it with one of the same size and strength (use Powerwinch Cable only—the winch rating and the cable strength are carefully matched), your warranty is void if any other cable is used.

J. NEVER use rope instead of cable. The potential for injury or damage is great.

K. DO NOT attempt to pull a load greater than the rated load of your winch.

L. DO NOT use your winch to hold or support the load once a job is done, or to secure the load properly, or you risk damage to your winch or the load.

M. NEVER wrap the winch cable around the load. Use an ecostrap or a chain to prevent the cable kinking or fraying.

N. ALWAYS wear leather gloves when handling the cable. Steel cable can be hard on hands.

O. We recommend the use of Powerwinch accessories and replacement parts.

CAUTION: When you finish using your winch DISCONNECT THE POWER CORD FROM THE SOCKET to avoid collection of moisture in the socket and prevent the danger of short circuiting.

NOTE: Any limited warranty which may apply to this product may be void if said product has been damaged due to accident, unreasonable use, neglect, modification, or failure to observe these safety recommendations.

TOOLS & MATERIALS REQUIRED

WRENCHES: 3/8, 9/16, 5/16, & 1/2

WIRE STRIPPERS

TERMINAL CRIMPER

SCREWDRIVER

3/8 & 5/16 Bolts & Nuts

Wire Ties
Rubber Grommets

SECTION I

FEATURES/PERFORMANCE & RATING

FEATURES / PERFORMANCE

CAPACITY:	Single Line Double Line	3,000 Lbs.* 5,000 Lbs.	1,500 Kgs. 2,500 Kgs.
LINE SPEED:	At No Load At No Load	14 Ft./Min.** 5 Ft./Min.**	4.25 M/Min. 1.53 M/Min.
POWER SUPPLY:		12 Volt DC***	
AMP DRAW:	At No Load At 3,000 Lbs.	12 + 2 Amps 80 ± 2 Amps*	
MAXIMUM DUTY CYCLE:		5 Min. ON 10 Min. OFF	
GEAR RATIO:		450:1	
WEIGHT:		34 Lbs.	20 Kgs.
BRAKING SYSTEM:		Adjustable Disc Type	
COLOR OF CASE:		Gray	

*Measured on first wrap.
**Fully-charged battery.
***24 Volt DC is available by special request

NOTE: Double line speed is half the single line speed.

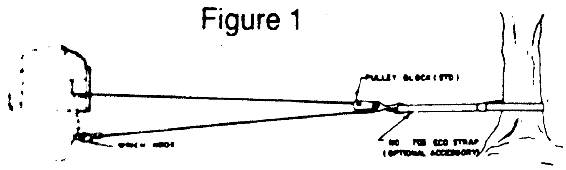
RATING

MAXIMUM WEIGHT: ROLLING LOAD (LBS.)

	SLOPE (DEGREE OF INCLINE)					
	10%	20%	30%	40%	50%	DEAD LIFT CAPACITY
	6°	11°	17°	22°	26°	
CONCRETE	26,150	14,450	10,150	8,000	6,700	3,000
GRAVEL	20,900	12,750	9,300	7,450	6,300	
MUDDY GROUND	15,700	10,600	8,150	6,700	5,850	
MUD	12,550	9,100	7,200	6,100	5,350	

SINGLE LINE: Capacity can be doubled with the use of a Powerwinch Pulley Block—Part #79043—for double line winching. see Fig 1

Figure 1



NOTE: This chart is valid for conventional, recreational and 4WD vehicles with air inflated rubber tires.

NOTE: 10% incline (or 6° is 1 foot rise in 10 feet).

NOTE: To convert from pounds (Lbs.) to Kilos (Kgs.) divide by 2.2

SECTION II

INSTALLATION/WIRING

NOTE: Be careful to mount your winch in a location with enough support to handle the rating of the winch. A little common sense when mounting will help eliminate hazards.

REAR VEHICLE MOUNT

For mounting on a vehicle with a trailer hitch we recommend the Powerwinch Multi-Purpose Adapter Plate (optional accessory #79085). This method is the most versatile, as movement from front of vehicle to the rear —or from vehicle to vehicle is possible.

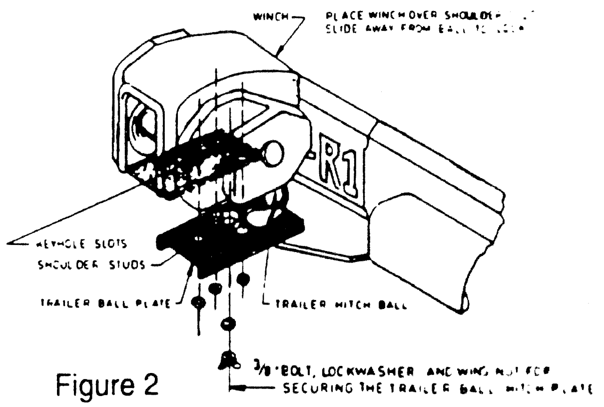


Figure 2

TRUCK BED MOUNT

The beds of most trucks are not made to support the pulling capacity of your Powerwinch, and should be reinforced with a steel plate capable of withstanding the rating of your winch.

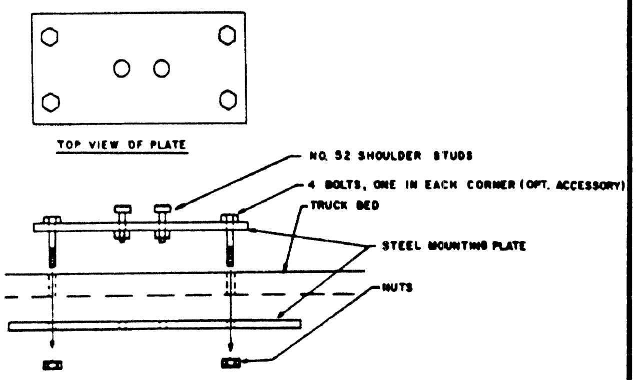


Figure 4

HAYBALER MOUNT

Instructions for mounting your winch to the haybaler should be included with your haybaler. If there are no instructions, the most important thing is to be sure your winch is adequately bolted to a location able to support the winch under full load conditions Use as steel backplate to spread the load where necessary.

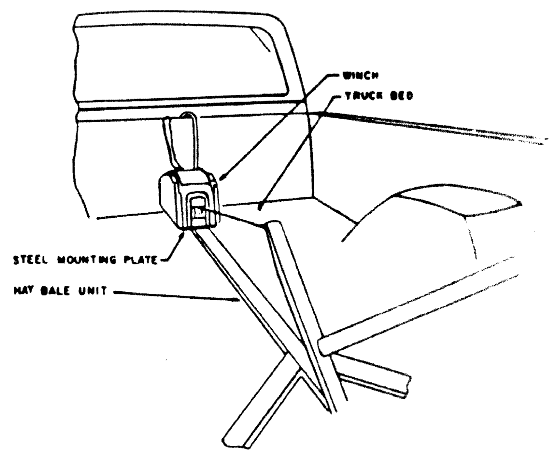


Figure 3

BH12 MOUNTING

Your winch may be mounted for overhead hoisting. Mounting for use as a hoist should be done carefully to avoid risk of damage or injury. While using as a hoist never stand under winch or load and follow all safety precautions.

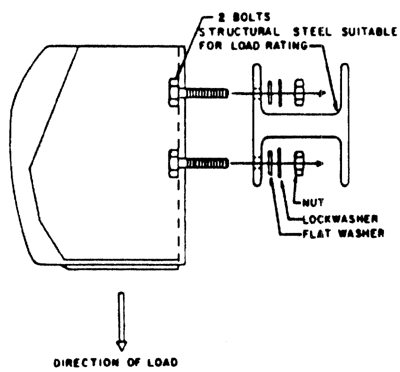


Figure 5

ROTARY SWITCH MOUNT

The rotary switch supplied has been designed to be permanently mounted although you may mount the switch in any location desired. The most common position is within reach on the dashboard.

CAUTION: The four metal contacts on the back of the switch must never touch grounded metal. This would cause a short circuit.

WIRING

The wiring assembly components supplied with your winch include:

LOOSE IN BOX:

1 ea. - 15 ft., #8 Red Wire (#78510, 78094)
1 ea. - 5 ft., #8 Black Wire (#78511, 78095)
1 ea. - 10 ft., #8 Duplex Wire - Gray with plug (#78574, 78338)

Owner's Manual and Warranty Card.

IN POLY-BAG

1 ea. - (3) Position Rotary Switch (#78101)
1 ea. - Circuit Breaker (#78322)
1 ea. - Up/Down Decal (#70357)
1 ea. - 8-5/16" Ring Terminal (#78602)
5 ea. - 8-3/16" Ring Terminal (#78601)

A. Connect the black wire to the negative (-) terminal of your battery or ground it to the vehicle frame. If you are mounting the winch to the rear of the vehicle, make the ground connection to the frame. Connect the other end of the black wire to the rotary switch (see schematic).

B. If the frame is used as a ground

1. Sandpaper both sides of the metal area where you are attaching the wire.
2. Attach the #8 - 5/16" ring terminal to the end of the ground (black) wire using a wire stripper and terminal crimper.
3. Attach the wire firmly to the frame using a 5/16" bolt, nut and lock-washer (not supplied) as shown in Figure 6.

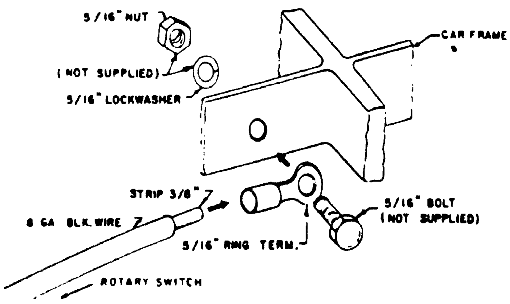


Figure 6

C. Attach the #8 - 3/16" ring terminal to one end of the red wire using a wire stripper and terminal crimper. Attach to the circuit breaker as shown in Figure 7. Place the wire where it can be easily attached to your starter solenoid or to the positive (+) terminal of your vehicle battery.

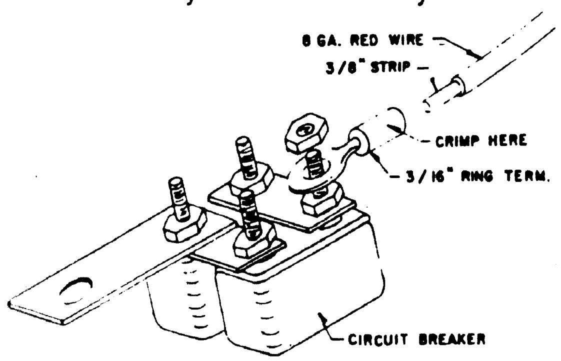


Figure 7

CAUTION: DO NOT CONNECT the circuit breaker to the starter solenoid or battery until all wiring installation steps are complete.

WIRING (con't)

D. Run the red wire under or through vehicle to the 3-position rotary switch. If you need to drill holes to feed the wires be sure the wires are protected from damage. It is a good idea to use rubber grommets (not supplied) to prevent the wire insulation from rubbing through and causing a short circuit.

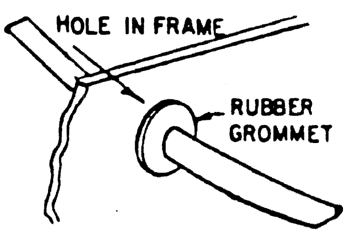


Figure 8

E. Use nylon wire ties (not supplied) to secure the wire to the frame of the vehicle about every 18" along the way You may also use electricians tape

CAUTION: Be sure wires do not hang down and are not located near moving parts, or hot areas (i.e., manifold, exhaust system) Incorrect wiring may short circuit and may damage your circuit breaker, vehicle or winch.

F. Check all wires to be sure they are securely tied down and connected to the rotary switch.

G. Connect the gray #8 duplex wire to the rotary switch as shown in the schematic. Check all connections to be sure they are tight.

H. Connect the circuit breaker to the starter solenoid, or battery, as shown below:

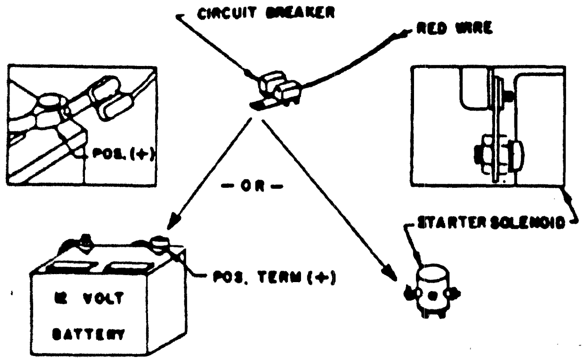


Figure 9

WIRING-TEMPORARY

To use your winch with a temporary wire hook-up:

A. Make all wiring connections as described in the wiring instructions—except wiring should not be run through the vehicle.

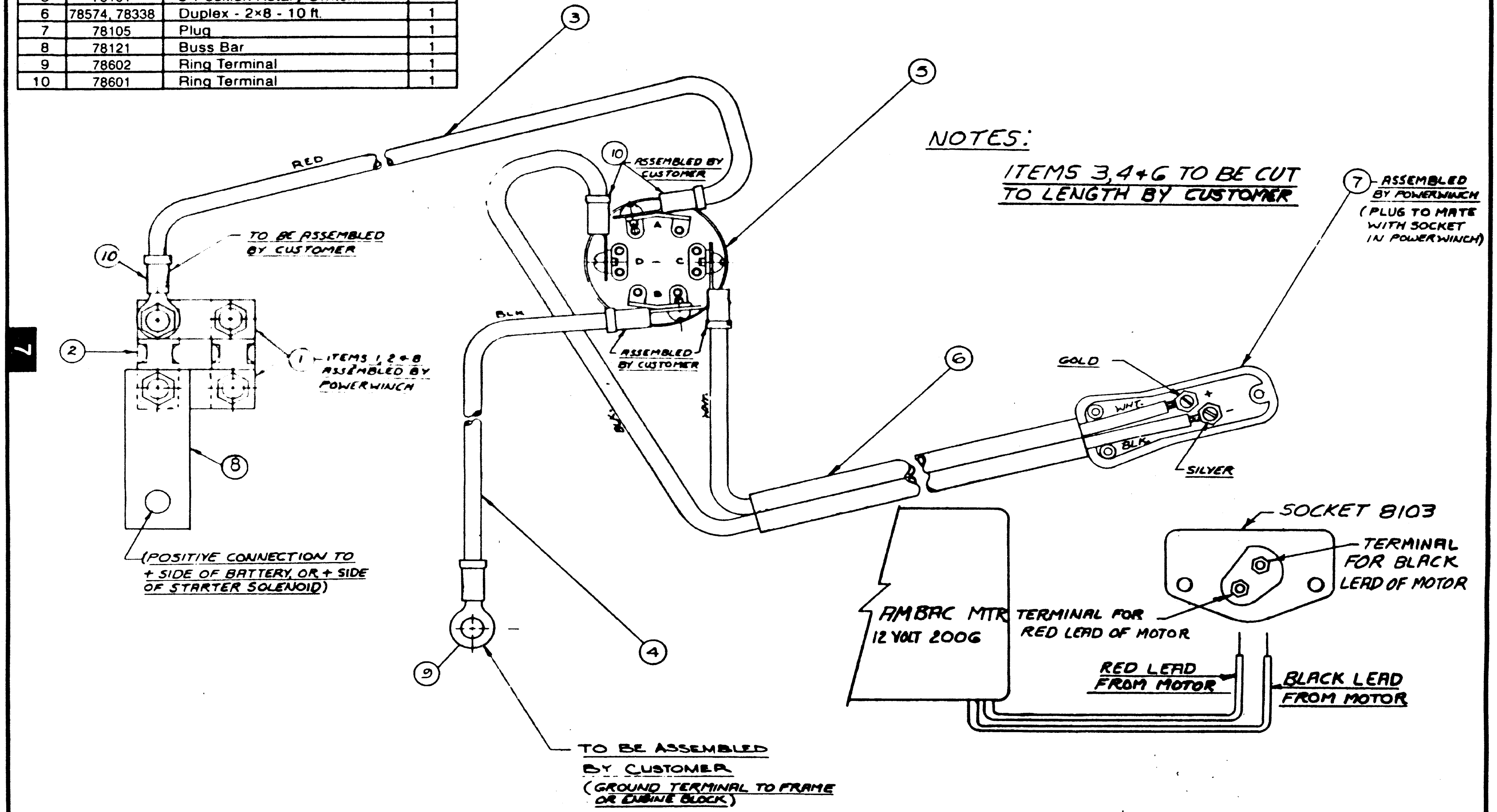
B. Attach two (2) alligator type clips. Attach one clip to the end of the black wire. Attach the other clip to the circuit breaker at the end of the red wire.

C. Run the red wire to the battery and clip it to the hot—positive (+) side.

D. Clip the black wire to the vehicle frame.

PARTS LIST			
Item	Part #	Description	Qty.
1	78122	Buss Bar	2
2	78106	Circuit Breaker	2
3	78510, 78094	Wire Assembly - 15 ft.	1
4	78511, 78095	Wire Assembly - 5 ft.	1
5	78101	3-Position Rotary Switch	1
6	78574, 78338	Duplex - 2×8 - 10 ft.	1
7	78105	Plug	1
8	78121	Buss Bar	1
9	78602	Ring Terminal	1
10	78601	Ring Terminal	1

WIRING SCHEMATIC



SECTION III

HOW TO USE YOUR WINCH

PREPARATION

Always leave the last three (3) turns of cable on the drum. This prevents the cable fastener from pulling out under heavy load.

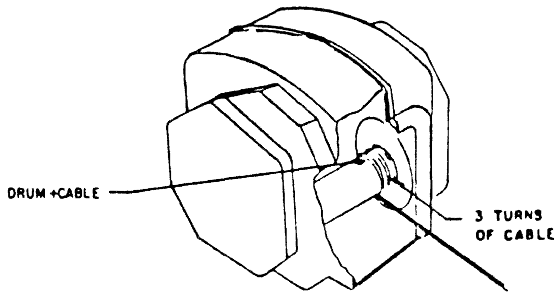


Figure 10

BRAKE SYSTEM & BRAKE ADJUSTMENT: Your winch has an adjustable disc brake. It is preset at the factory to hold a load of 500 Lbs. (227 Kgs.). If a heavier or lighter load is to be held you will need to adjust the brake.

REMEMBER:

A. The tighter the brake the greater the holding power.

B. The looser the brake the lesser the holding power.

Look at the figure below, you can see there is an outer and inner nut.

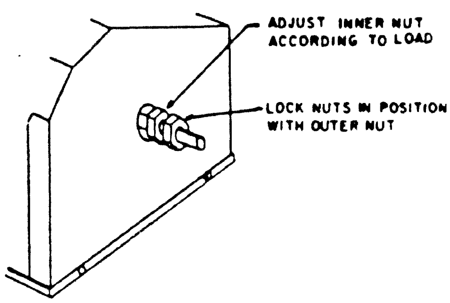


Figure 11

1. If the load is more than 500 Lbs., tighten the inner nut. The inner nut should be tight enough to keep the load from slipping or "creeping" but—

CAUTION: Do not overtighten the inner nut. This will shorten the life of the motor.

2. If the load is less than 500 Lbs., loosen the inner nut as much as possible. Again, be aware of the warning above.

When you have made the brake adjustment, tighten the outer against the inner nut using a wrench. This will lock them together and prevent accidental loosening.

NOTE: A friction brake holds the load when the power is off.

"DEADMAN" CABLE

Do not wrap the cable around a load and hook to self. When attempting to do this use the Powerwinch "eco-strap" to insure the cable does not fray or kink. See below for do and don't examples.

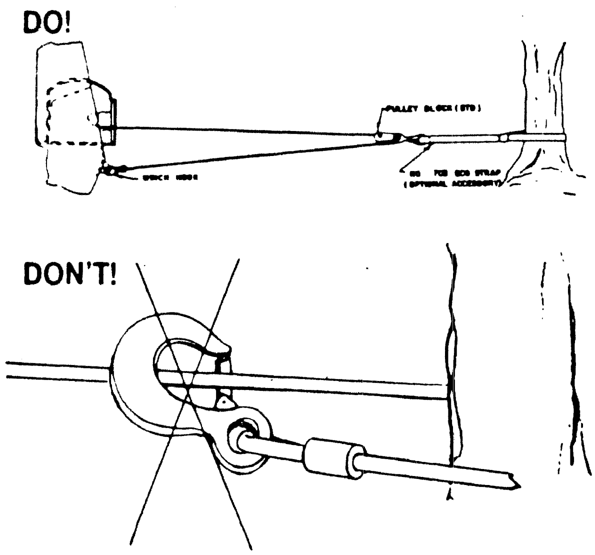


Figure 12

SECTION IV

TROUBLESHOOTING

NOTE: If your winch fails to operate the problem may be either electrical or mechanical.

ELECTRICAL

CAUTION: Disconnect power while removing parts and reconnect to test.

If your winch fails to operate, the chances are that the problem is electrical.

A. Start checking at your battery (or starter if that is where you connected the circuit breaker).

B. By-pass the circuit breakers. If your winch now works, you need a new circuit breaker (see parts list). It is suggested you carry a spare circuit breaker for emergencies.

C. Check your wiring insulation to see that there are no bare spots that may be causing a short.

D. Check your connections to see that they are tight.

E. Check the male connection at the end of the wiring kit by using a probe light across the two prongs inside the plug. If you get a light, your wiring is okay.

F. Remove screws (#79584 - Key #33) and cover rods (#75603 - Key #44) from the side of the case containing the female socket. Plug the male plug into the female socket. Use a probe light across the two connections on the underside of the female socket.If you had a light when testing the male plug but do not get a light now, your female socket is at fault. If you get a light at this point, test the switch.

G. To test the switch, use a jumper wire to bypass the switch being careful to keep your fingers away from the winch mechanism. If you now get power to your motor your switch is at fault. If you don't get power, it is likely that your motor is at fault.

MECHANICAL

A. Remove the case and check for broken or worn parts. Replace as required.

B. If the winch clutch doesn't hold the load, tighten the inner nut on the clutch shaft until the load is stable. If the clutch is still slipping, check clutch lining and clutch gear for wear. Replace as required.

C. Remove the cover and lubricate the gears once a year with a lithium base grease.

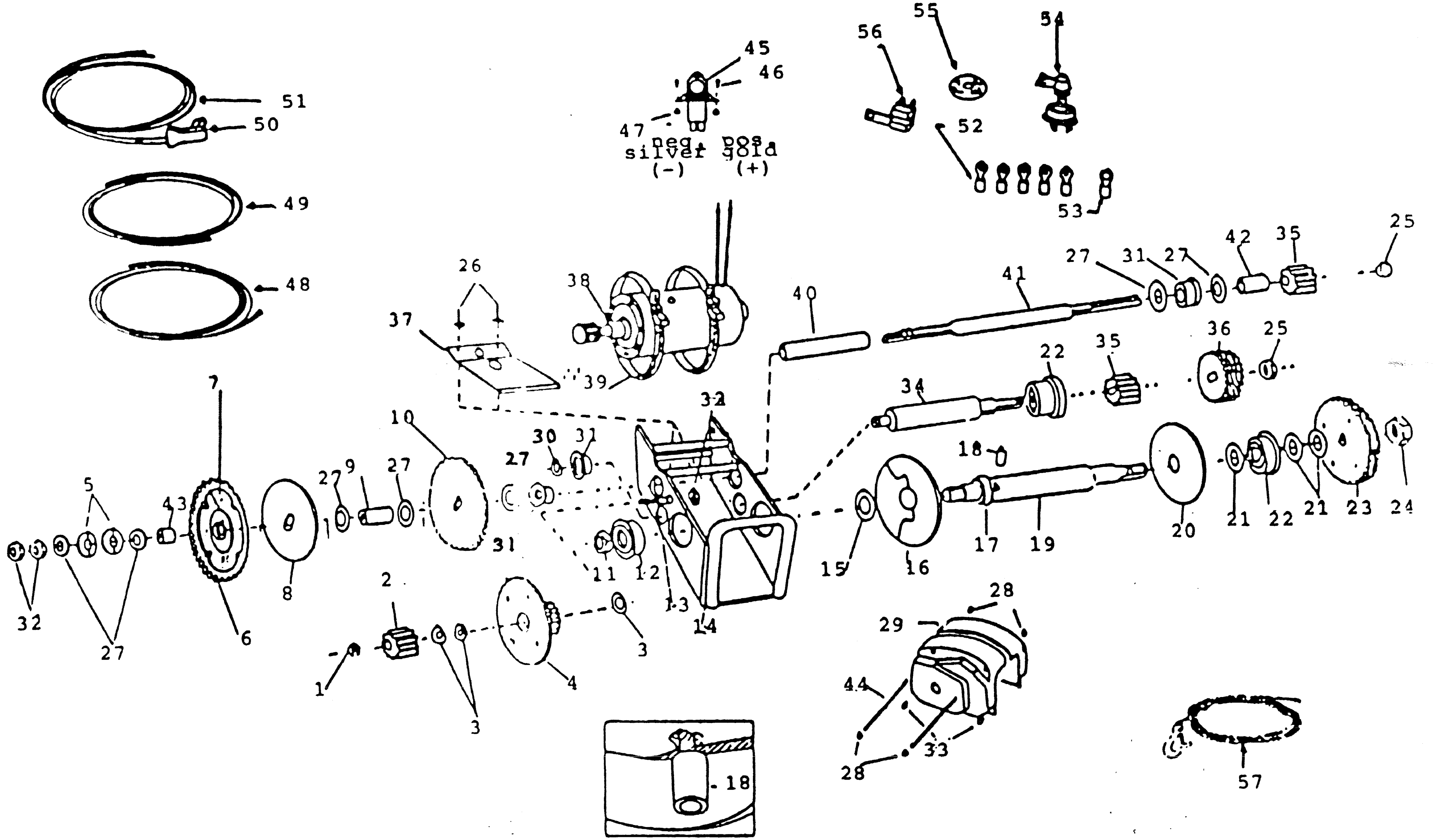
STILL . . .

If you still have a problem with your winch:

A. Take the unit to a Powerwinch repair station. For the station nearest to you, call our service department at 1-800-243-3097.

B. Your other option is to put the unit in a box and ship it prepaid to Powerwinch. We'll repair it at no charge for the first two years—and ship it back to you within three working days. Please call us first at the number above.

SECTION V EXPLODED PARTS DRAWING



PARTS LIST

KEY #	PART #	ID #	DESCRIPTION	QTY USED
1	—	79852	Retainer	1
2	C12	71776	Pinion Brake Assembly	1
3	C25B	71613	.060 Thrust Race	3
4	CH30	71752	Drive Gear	1
5	H26S	71904	Spring Washer	2
6	H26	71757	Laminated Clutch	1
7	H26D	73604	Clutch Lining	1
8	25	75302	Pinion Gear Clutch Plate	1
9	—	71508	Spacer "D"	1
10	C34R	71703	Powdered Metal Gear	1
11	33	79712	1/2-20 Nut	1
12	6	71605	Bearing	1
13	—	71311	1st Gear Shaft	1
14	CT1R	70139	Frame	1
15	6A	71820	Spacing Washer	1
16	C5	71953	Drum Shaft Flange	1
17	—	79088	Drum Collar	1
18	S3AR	71858	7/32 Cable Fastener	1
19	—	71312	Drum Shaft	1
20	C2	71951	Drum Shaft Flange	1
21	T6A	71821	Spacing Washer	3
22	T6	71606	Bearing	2
23	R8	71751	Gear	1
24	R10	79716	3/4-16 Hex Nut	1
25	33	79712	1/2-20 Hex Nut	2
26	—	79918	3/16 Pop Rivet	2
27	C6A	71822	Spacing Washer	8
28	C41N	79719	Acorn Nut	4
29	—	74171	Cover (SH12HBM)	4
		74017	Cover (BH12)	
30	R13	79851	Snap Ring	1
31	T13	71608	Bearing	2
32	—	79713	1/20-20 Shaft Nut	2
33	C41S	79566	Cover Screws	4
34	C55	71301	Intermediate Shaft	1
35	C12	71704	Pinion Gear	2
36	56	71708	Idler Gear	4
37	205	70205	Levelwind Plate	1
38	1736	72015	Motor with Gear	1
39	23	72203	Motor Straps	2
40	1819	71819	Rear Shaft Spacer	1
41	CT14	71211	Rear Shaft	1
42	C14B	71817	Shaft Spacer "B"	1
43	C14A	71816	Shaft Spacer "A"	1
44	C41R	75603	Cover Rod	2
45	P19R	78103	Socket	1
46	—	79569	10-32 x 1/2 Screw	2
47	P39R	79701	10-32 Hex Nut	2
48	420A	78510	15 ft. 8 ga. Red Wire (SH12HBM)	
		78094	15 ft. 8 ga. Red Wire (BH12)	
49	420	78511	5 ft. 8 ga. Black Wire (SH12HBM)	1
		78095	5 ft. 8 ga. Black Wire (BH12)	
50	P47B	78105	Plug (SH12HBM and BH12)	1
		78167	Plug Boot (BH12)	
51	—	78574	10 ft. 8 ga. Duplex Wire (SH12HBM)	1
		78338	Wiring Harness (BH12)	
52	—	78601	8-3/16" Ring Terminal	5
53	—	78602	8-5/16" Ring Terminal	1
54	H17	78101	Switch	1
55	—	70357	Up/Down Decal	1
56	S47A	78322	Circuit Breaker	1
57	S45	71872	7/32 x 25' Cable (SH12HBM)	1
		71857	7/32 x 45' Cable (BH12)	

SECTION VI

WARRANTY

LIMITED WARRANTY

A. This Limited Warranty is given by the Powerwinch Division of the Scott Fetzer Company (the "Company") to the original purchaser ("Purchaser") of a Powerwinch Winch, Model #SH-12-HBM (the "Product"). This Limited Warranty is not transferable to any other party.

B. Responsibilities of the Company under this Limited Warranty:

1. Repair or replace (at the discretion of the Company) any part or parts of the Product found by the Company to be defective within a two (2) year period from date of purchase.
2. The Company will pay the transportation charge for shipment back to the Purchaser for any Product received for legitimate Warranty repair.

C. Responsibilities of the Purchaser under this Limited Warranty:

1. Complete (fully and accurately) and return to the Company the Warranty Card included in the box. Otherwise Purchaser will have to show dated proof of purchase to qualify for service under the provisions of this Limited Warranty.
2. Promptly notify the Seller or the Company of any claim hereunder
3. At the Option of the Company, return the Product to the Company for inspection. Authorization must be given prior to any Product return. Call the Company at 1-800-243-3097, or write the Company at 100 Production Drive, Harrison, Ohio 45030, for authorization and complete instructions on how to return the Product directly to the Company.

Powerwinch reserves the right to alter specifications on any product without notice.

4. Use reasonable care in maintenance, operation, use and storage of the Product in accordance with the instructions contained in the Owner's Manual.
5. Have Warranty work performed by a dealer or representative approved by the Company.
6. Except as provided in B.2. above, transportation charges are the responsibility of the Purchaser.

D. This Limited Warranty covers:

1. Defects in workmanship or materials.
2. Any part or parts of the Product sold or manufactured by the Company.

E. This Limited Warranty does not cover:

1. Any failure that results from improper installation of the Product.
2. Any failure that results from accident, Purchaser's abuse, neglect, modification, improper maintenance, or failure to operate and use the Product in accordance with the instructions provided in the Owner's Manual supplied with the Product.

F. THERE IS NO OTHER EXPRESS WARRANTY. IMPLIED WARRANTIES, INCLUDING THOSE OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED TO TWO (2) YEARS FROM DATE OF PURCHASE. THIS IS THE EXCLUSIVE REMEDY AND ANY LIABILITY FOR ANY AND ALL INCIDENTAL OR CONSEQUENTIAL DAMAGES OR EXPENSES WHATSOEVER IS EXCLUDED. Some states do not allow limitations on how long an implied warranty lasts, or do not allow exclusion or limitation of incidental or consequential damages, so the above limitations may not apply to you. This Limited Warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

Powerwinch
Factory Authorized Service Centers

Alabama	Theodore 36582	G & S Repair 5663 Plantation Road	(205) 653-0039
California	San Francisco 94107	Park Presidio Marine 1300 A, 25th Street	(415) 821-2628
Connecticut	Manchester 06046	Blish Air Tool 472 Center Street	(203) 649-4323
	Hamden 06514	Baltimore Electronics 1348 Dixwell Avenue	(203) 248-7553
Florida	Ft. Lauderdale 33334	Master Repair 4107 NE 6th Avenue	(305) 565-3001
	Ft. Lauderdale 33304	Sportsman Trading Post 1771 E. Sunrise Blvd.	(305) 467-7872
	Jacksonville 32204	Schumann Casters & Equipment 1299 West Beaver Street	(904) 356-2322
	Orlando 32805	Hagood Brothers 1121 W. Church Street	(305) 843-4220
	Sarasota 33580	Barry Trailers 1801 N. Washington U.S. 301 North	(813) 953-3468
	Tampa 33602	T A Mahoney 321 S. 13th Street	(813) 225-1634
	W. Palm Beach 33409	The Tool Depot 2532 Old Okeechobee Rd.	(407) 689-6215
Louisiana	Houma 70363	Le Blanc Service Inc. 207 Clendenning	(504) 868-6755
	Many 71449	Mid-Lake Marine Center Route 1, Box 725 Highway 6, West	(318) 256-5573
Maryland	Princess Anne 21853	Del Marva Marine U.S. 13, Bypass	(301) 651-1568
	Crisfield 21817	Carson's Marine Inc. Main St. PO Box 41	(410) 968-0565
	Secretary 21664	Budds Sales & Service Box 132	(410) 943-4288
Massachusetts	W. Wareham 02576	Richard St. John 52 Leonard Street	(508) 748-0021
Minnesota	Bloomington 55431	Marine Electric Co. 9804 James Circle	(612) 881-0077
	Minneapolis 55411	Penn Electric Motor Service 2515 W. Broadway	(612) 588-5333
Missouri	Cameron 64429	Stewart Enterprises RR 2, Box 33C	(816) 632-6578
	Ozark 65721	Tri-L Manufacturing RR 2, Box 57, MN Hwy	(417) 485-6820
	Williamstown 63473	Morris, Inc., RR 1, Box 115	(314) 853-4473
New Jersey	Belford 07718	Mariners Mart 154 Highway 36E	(201) 787-1100
	Brigatine 08203	Jersey State Marine 601 Bayshore Av	(609) 266-7011
	Mapleshade 08052	South Jersey Marine Outlett Rt. 38 Rudderow Avenue	(609) 482-1501
	Port Monmouth 07758	Port Monmouth Marine 116 Hwy 36	(201) 787-1835
	Rio Grande 08242	Jersey Cape Marine Le Ric Plaza Rts. 9 & 47	(609) 886-2270
New York	Commack 11725	American Marine 2161 Jericho Turnpike	(516) 543-6433
North Carolina	Beaufort 28516	C & H Marine, Rt. 4, Box 61A	(919) 728-2411
Oregon	Portland 97236	J & L Equipment 12346 S.E. Raymond	(503) 760-6117
Pennsylvania	Williamsport 17701	Professional Petroleum Svc. Co 2500 New Lawn	(717) 322-5524
	Port Trevorton 17864	Keller Marine, Rts. 11 & 15 (717) 374-8169	(717) 374-8169
South Carolina	Charleston 29407	John's Rod and Reel 47 S. Windermere Blvd.	(803) 766-7300
Tennessee	Memphis 38126	Authorized Equipment Service 812 Polk Avenue	(901) 774-0850
Texas	Houston 77096	Appliance Hospital 4530 Beechnut	(713) 668-6705
Virginia	Accomac 23301	Accomac Marine Rt. 13 North	(804) 787-8915
	Cape Charles 23310	Cape Charles Marine P.O. Box 342 U.S. 13 & Rt. 641	(804) 331-2414
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Powerwinch
100 ProductionDr.
Harrison, OH 45030 USA
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513/367-4811

Powerwinch

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100 Production Drive
Harrison, OH 45030

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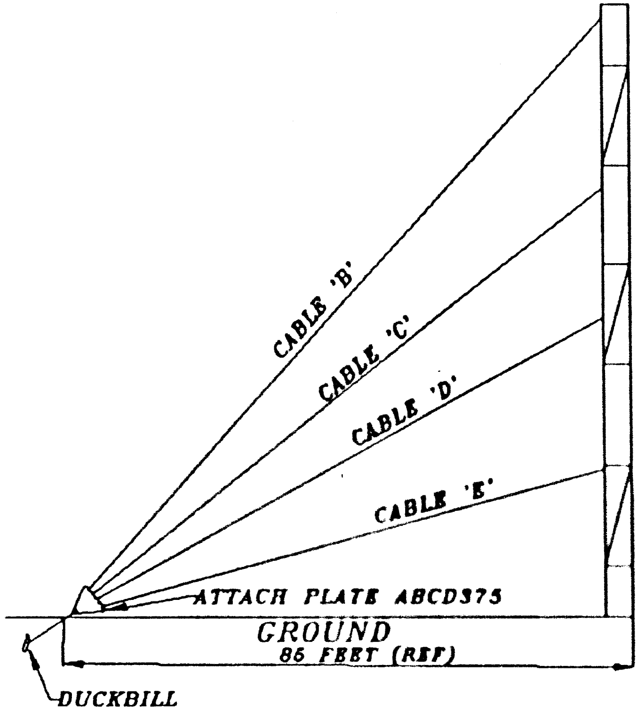
Dear Customer:

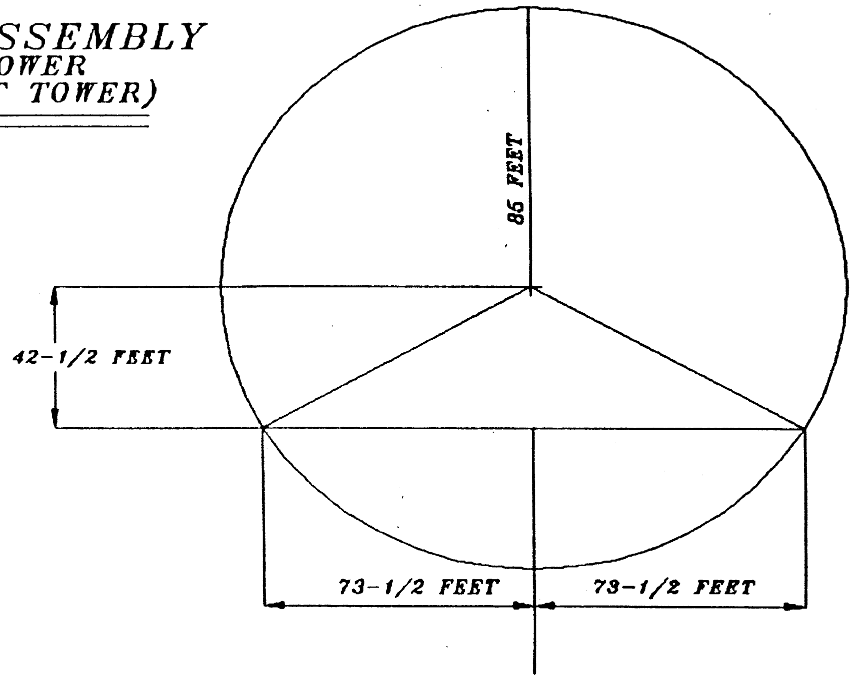
Thank you for purchasing this Powerwinch product. We want to be sure that you are completely satisfied with your purchase.

If you have a question or concern, call 1-800-243-3097 and we will resolve your problem or answer your question immediately. Please have the model number and serial number from the unit before you call.

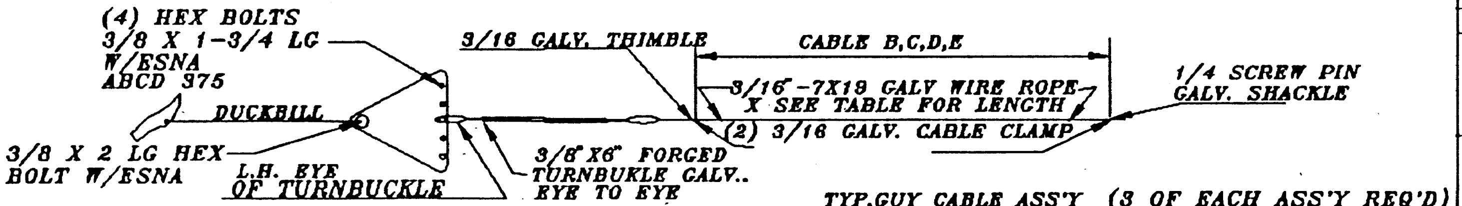
If you have a suggestion or recommendation on how we can better serve our customers, please call us.

TOWER GUYING ASSEMBLY
–3 REC'D PER TOWER
(EQUISPACED ABOUT TOWER)



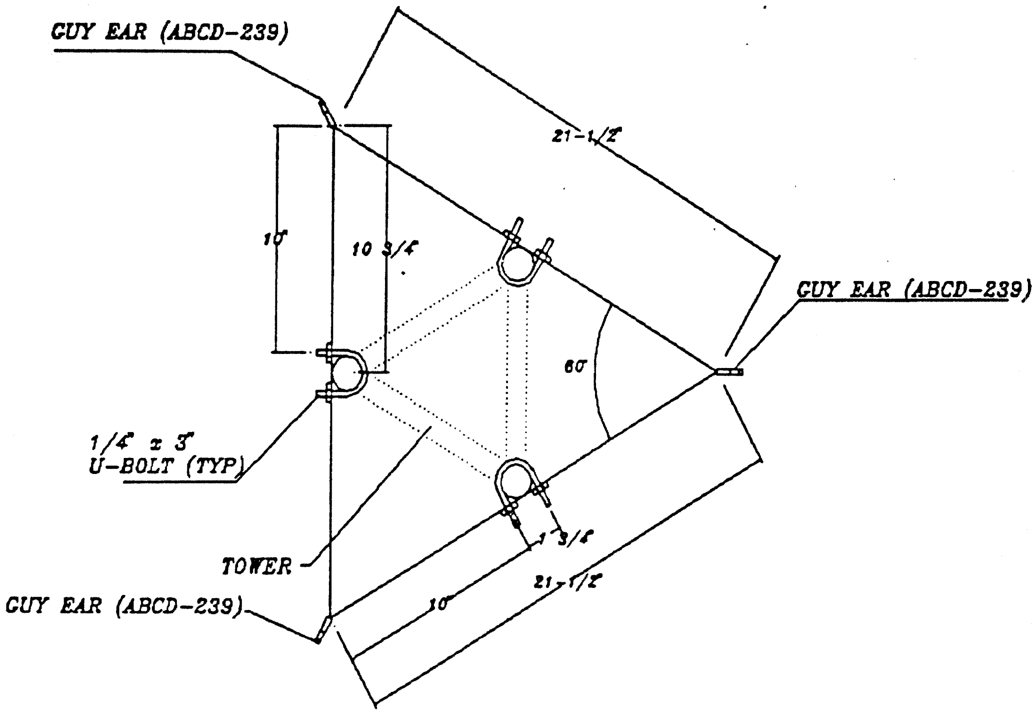


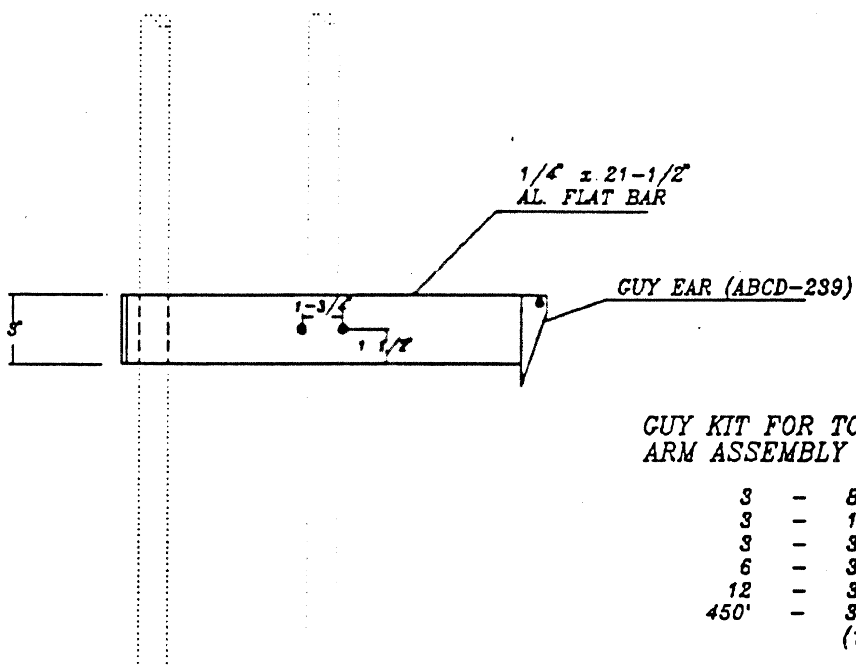
DR-3 DRIVE ROD	88 DB-1 DUCKBILL	NUMBER	WIRE ROPE NUMBER	LENGTH EYE TO EYE	GALV. WIRE X LG. IN FT.	1/4 SCREW SHACKLE	3/16 CABLE CLAMP	3/16 THIMBLE	3/8 X 6 TURNBUCKLE	ATTACH PL. ABCD 375
TOTAL OF 1	1 PER GUYING ASS'Y	3	CABLE 'E'	90'	3/16" (7x19)	1	4	2	1	TOTAL OF 3
		3	CABLE 'D'	102'	3/16" (7x19)	1	4	2	1	
		3	CABLE 'C'	118'	3/16" (7x19)	1	4	2	1	
		3	CABLE 'B'	138'	3/16" (7x19)	1	4	2	1	
1	3	TOTAL REQ'D		3/16" (7x19)x1400 FEET		12	48	24	12	3



TYP.GUY CABLE ASS'Y (3 OF EACH ASS'Y REQ'D)

ALUMA TOWER COMPANY INC. VERO BEACH FL. 32960	
FRB	3-1-94
#4-30 CG GUY KIT W/#8800 ANCHOR	
T-100 B,C,D,E SECTIONS	#4-30 CG





GUY KIT FOR TORQUE
ARM ASSEMBLY (30')

3	-	88-DB-1
3	-	1/4 SCREW SHACKLES
3	-	3/8 - 6 TURNBUCKLE
6	-	3/16 THIMBLES
12	-	3/16 CABLE CLAMPS
450'	-	3/16 (7x19) GALV. WIRE (150' PER SIDE)

REV 4-7-94 GUY KIT ADDED FRB

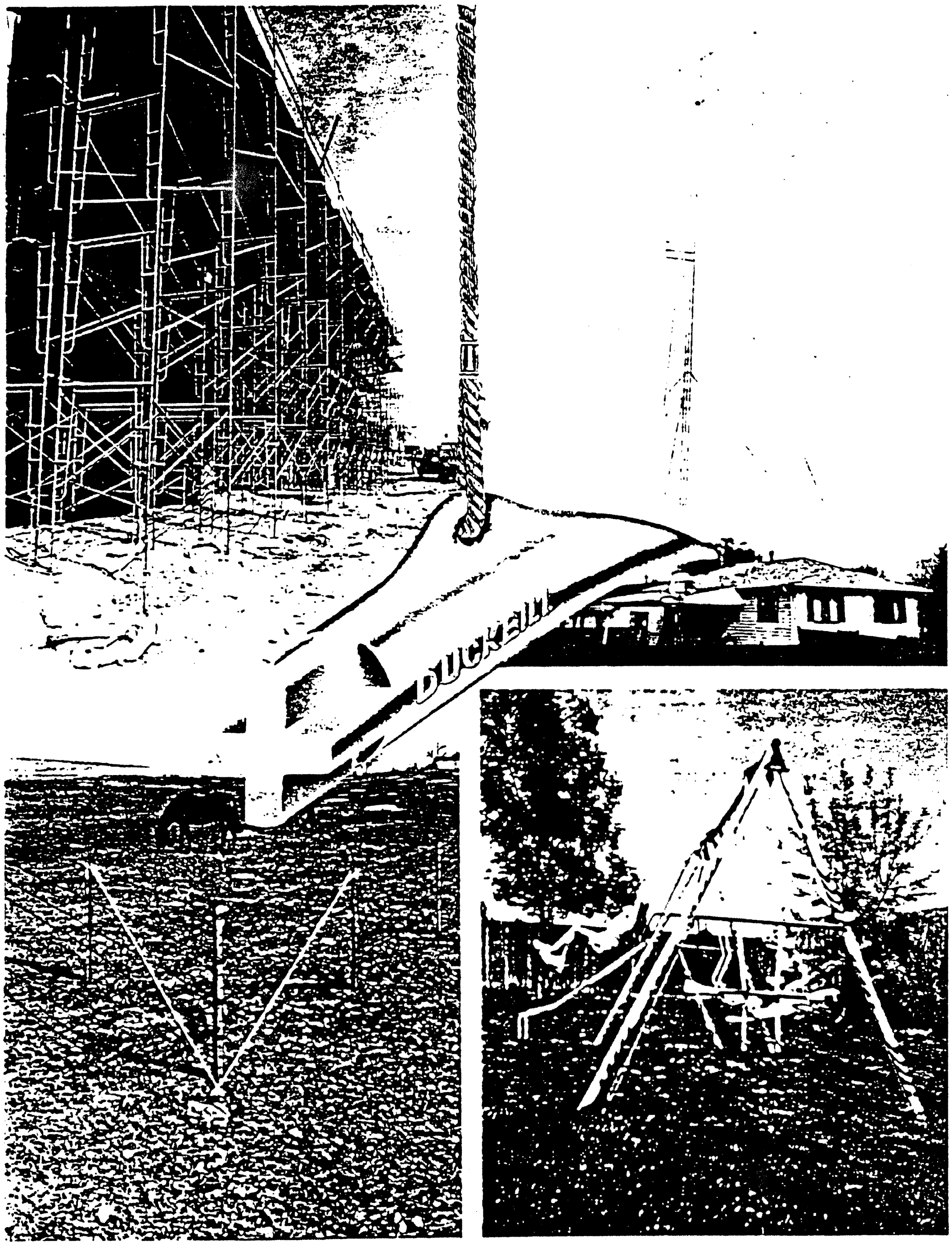
ALUMA TOWER CO. INC

VERO BEACH FL. 32960

TORQUE ARM ASSEMBLY

DRW BY FRB	SCALE	DRWN. No. BCD-699 REV 'A'
CHK BY	DATE 3-1-94	
TRACED	APP'D	

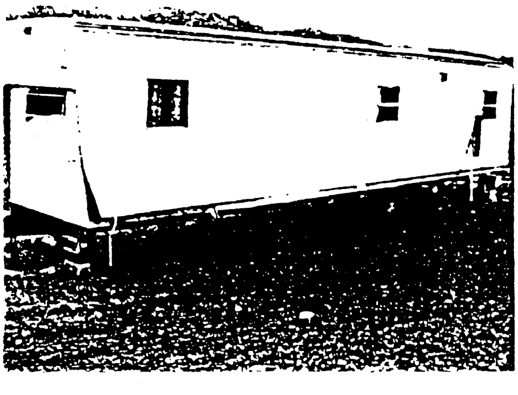
DUCKBILL
Earth Anchor Systems

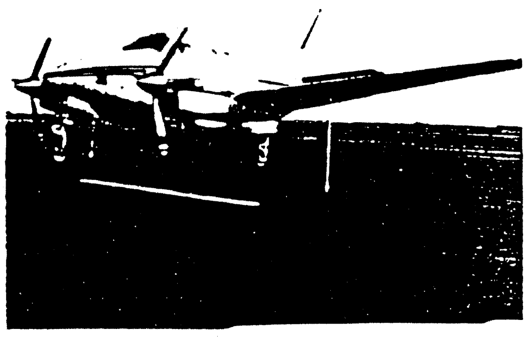


UNIVERSAL EARTH ANCHORS

Duckbill Earth Anchors are used worldwide to secure any object that can be stolen, moved or blown down by the wind. The Duckbill, available in different sizes and capacities for many applications, is truly universal. Among its many uses: trees, antennas, scaffolding, playground equipment, fences, airplanes, signs, sheds, mobile homes, large bushes, winches, towers, pipelines, boats and many more objects.

Duckbill is a labor and time saving device. One man drives Duckbill with manual or hand-held power tools. No digging, no expensive machinery, no crew of workers, no special skills needed. And Duckbill is safer than conventional anchors because it leaves no rigid rods or stakes above ground to injure people or damage mobile equipment.





DUCKBILL®
Earth Anchor Systems

RECOMMENDED INSTALLATION GUIDELINES

OF THE

DUCKBILL ALUMINUM EARTH ANCHOR SYSTEM

FORESIGHT®
PRODUCTS INC.

A RESEARCH, DEVELOPMENT AND MARKETING COMPANY

Further information ...

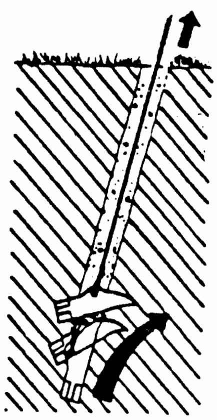
is available from Foresight Products, Inc.,
10780 Irma Dr., Unit 22
Northglenn, CO 80233
Phone: 1-800-325-5360
(303) 457-0222

INTRODUCTION

This guide serves to aid suppliers and installers of DUCKBILL earth anchors about installation methods and techniques. The DUCKBILL earth anchor has been developed to function in the total range of soils. Its design allows the installer much greater flexibility than competetive anchors offer. Installation details, tools and special soil conditions will be covered and should answer any questions that may arise. DUCKBILL anchoring systems offer an economic, lightweight solution to nearly any anchoring situation, big or small. Normally, wherever you can drive a stake or drill a hole you can use a DUCKBILL anchor.

THE DUCKBILL PRINCIPLE

The DUCKBILL anchor works very much like a toggle bolt. The anchor body is driven into the soil with a re-useable drive rod. Once the anchor body is placed to the proper depth the drive rod is removed. A backward pull on the cable then rotates the anchor body in the ground until it is perpendicular to the cable. This is called load-locking the anchor.



Because the DUCKBILL is usually driven into the earth it is actually compacting the soil, not disturbing it. As the anchor is load-locked it cuts through the compacted soil into undisturbed soil and further compacts the soil above the anchor. As the soil above the anchor is compacted from below it forms an inverted cone of compact soil. This is called a cone of resistance.

One of the most important features of the DUCKBILL anchoring concept is the ability to proof-test the anchor during normal installation. The load locking operation can be a proof-test of the anchor. By measuring the force required to load-lock the anchor the installer knows the actual holding capacity of the installation.

SOILS

CLASS	DESCRIPTION	PROBE VALUE
1	Solid Bedrock	--------
2	Dense Clay; Compact Gravel Dense Fine Sand; Laminated Rock; Slate; Schist; Sandstone	Over 600 in./lbs.
3	Shale; Broken Bedrock; Hardpan; Compact Gravel Clay Mixtures	500-600 in./lbs.
4	Gravel; Compact Gravel and Sand; Claypen	400-500 in./lbs.
5	Medium-Firm Clay; Loose Standard Gravel; Compact Coarse Sand	300-400 in./lbs.
6	Medium-Firm Clay; Loose Coarse Sand; Clayey Silt; Compact Fine Sand	200-300 in./lbs.
7	Fill; Loose Fine Sand; Wet Clays; Silt	100-200 in./lbs.
8	Swamp; Marsh; Saturated Silt; Humus	Under 100 in./lbs.

Table provided by A. B. Chance

Anchor holding capacity will vary in the different classes of soils. More capacity can be expected in the numerically lower classes and less capacity in the higher classes. Knowing the type of soil does not always mean that the class is known. For example, a clay material can have a class ranging from 4 to 8 depending on whether the material is very stiff to hard or soft to very soft. Water content will also affect classification. Similarly cohesionless soils such as sands and gravels have a wide range depending upon the density or compactness of the material.

There are various ways of testing soils. A torque probe is the best for quick classification in the field. Core samples are the best for detailed classification but are expensive and take time to obtain the test results. Generally resistance to driving the DUCKBILL is a good "seat of the pants" indicator of soil class. Stiff resistance will normally result in positive anchoring. If the anchor drives very easily the soil is soft and steps should be taken to assure adequate capacity. Keep in mind that simple proof-loading will verify the capacity of the anchor in any soil class.

ANCHORS

DUCKBILL MODEL #	RATED CAPACITY	DRIVE ROD DIAMETER	NORMAL DEBTH OF INSTALLAT
40	300 lb.	1/4"	20"
68	1,100 lb.	1/2"	2½'
88	3,000 lb.	3/4"	3½'
138	5,000 lb.	1" or 1 1/8"	5'

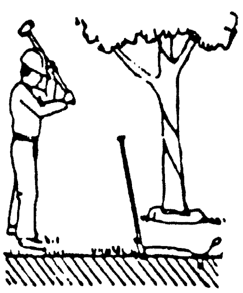
The anchors are rated in an average (class 5) soil condition. Again, higher capacities can be expected in harder soils and lower capacities in softer soils. The rating is mainly useful as a reference for anchor selection. Proof-loading is the only way to insure the exact capacity of each installation. This is true for all anchors on the market today.

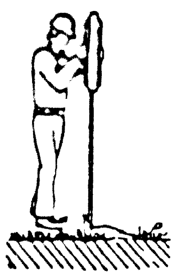
INSTALLATION

The first step in any installation is to select the proper anchor for the job. Keep in mind the maximum load expected and add a reasonable safety factor.

DRIVING THE ANCHOR

The DUCKBILL can be driven to almost any depth at any angle. In guy applications the angle of the installation should closely match the angle of the guyline. Start by inserting the steel drive rod into the anchor body. Use a sledge hammer, fence post driver or a power driven jack-hammer to drive the anchor to the proper depth.



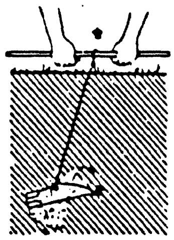


LOAD LOCKING THE ANCHOR

After the anchor has been driven to depth the drive rod is extracted from the anchor. Pull back on the anchor cable to toggle the anchor into the perpendicular (load-locked) position. In average soils a rule of thumb is that the length of pull should be somewhat longer than the length of the anchor body.

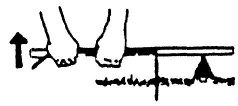
For example: Model 88 anchor body measures 4 3/4" inches.
A pull of 5"-6" will rotate the anchor into a completely perpendicular position.

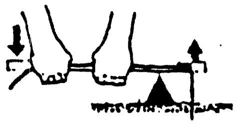
Several methods are used to load lock the anchors.



LOAD LOCKING BY HAND

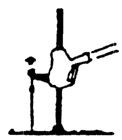
The smaller DUCKBILL models may be locked by hand. Insert the drive rod through the cable loop or wrap the cable about the drive rod to fashion a "T" handle. Pull on the drive rod to load-lock the anchor. A fulcrum is also very useful in locking anchors by hand. Two methods are commonly used.

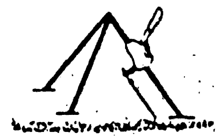




JACKS

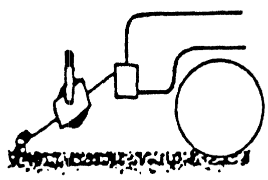
Ordinary automotive bumper jacks or handyman jacks work well on medium and larger sized anchors. By adding legs to the jack to form a tri-pod angled pulls are achieved with greater ease.





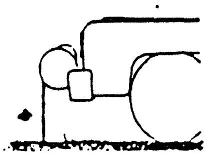
COME-ALONGS AND FENCE STRETCHERS

These tools work very well providing that there is a substantial counter anchor nearby. A truck bumper for example. In general the object that is to be guyed is not acceptable as the counter anchor. It will deflect prior to the anchor reaching full load-lock position.



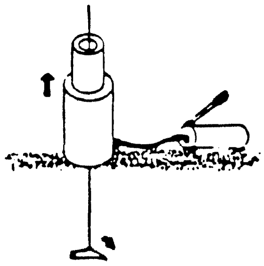
WINCHES

An automotive power or hand winch is good for locking the larger models. Know the capacity of the winch and be careful not to inadvertently overload the anchor.



CENTER HOLE HYDRAULIC CYLINDERS

Although a specialized piece of equipment, the center hole hydraulic cylinder is a very good tool for someone who will install many anchors on a regular basis. Being small and lightweight they are ideal for horizontal installations. A hydraulic pressure gauge often accompanies this set-up so that every installation may be checked for capacity. (proof loading)



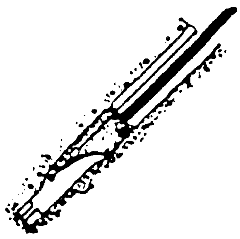
No matter what method is used it is critical that the anchor be properly locked before tying off the object to be anchored. An anchor not properly locked prior to attaching will result in significant pull out before the anchor self locks. Obviously this is not desired.

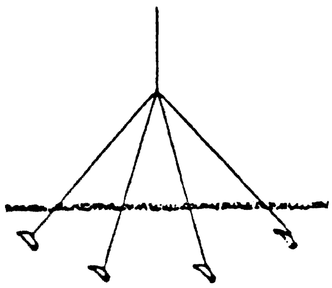
Failure to install and lock the anchor at the correct angle will result in the anchor cable cutting through the soil until the angles equalize. This will cause slack in guylines. Also not desired.

SPECIAL SOILS CONSIDERATIONS

SOFT SOILS

In areas where the soil proves to be softer than normal steps should be taken to assure the capacity of the anchor. Proof-loading is especially useful in soft soils. Guesswork as to the capacity is eliminated. The installer will know immediatly if the anchor point is adequate or if further steps are necessary. Backfilling and tamping the hole behind the anchor will yield somewhat higher capacity in most soft soils. Fill and tamp the hole in 3" lifts prior to load locking the anchor. Another option is to drive the anchor deeper in an effort to penetrate a harder layer of soil. Larger anchors may need to be placed to achieve the required load. As a last resort a number of anchors may be placed in a cluster and bridled together to form one point.





HARD SOILS AND ROCK

If excessive resistance to driving occurs it may be necessary to drill a hole for anchor placement. If the anchor stops moving and is subjected to excessive pounding (especially from power equipment) metal fatigue can occur and the anchor body can fracture. The DUCKBILL anchor may be placed in a pre-drilled hole in hard dirt or rock and achieve very good results. Hand augers and gasoline or hydraulic powered earth drills can be used to form the hole. A PIONJAR 120 gasoline powered breaker/drill is very useful due to the fact that it performs both drilling and driving operations.

SIZES OF PRE-DRILLED HOLES

model 68	1 1/4" to 1 1/2"
model 88	1 3/4" to 2 1/4"
model 138	2 1/2" to 3"

The small end of the range is satisfactory in hard dirt situations. The high end of the range must be used for anchoring in solid rock.

The information included in this publication is only for general purposes. The conditions on each individual job site will dictate the proper anchor and tools necessary to achieve a quality installation.

DUCKBILL®
Earth Anchor Systems

FORESIGHT PRODUCTS INC.

U.S. Patent numbers 4,044,513 and 4,096,673 and other international patents. Additional patents pending.

LL-2

MEDIUM CAPACITY MANUAL LOAD LOCKER

OWNER'S MANUAL

6430 East 49th Drive
Commerce City, CO 80022
800-325-5360 / 303-286-8955
Fax 303-287-3866

Safety Precautions

* * * WARNING * * *

BEFORE USING THE LL-2 TO PROOF LOAD OR EXTRACT ANCHORS BE SURE TO ADHERE TO ALL COMMON SAFETY PRECAUTIONS USED BY EVERY UTILITY, CABLE TV COMPANY, CONTRACTOR OR CONSTRUCTION COMPANY. HARD HATS, SAFETY BOOTS, SAFETY GLASSES MUST BE WORN.

* * * WARNING * * *

ALL UNDERGROUND WORK REQUIRES PROPER LOCATION PROCEDURES OF INSITU HAZARDS BY QUALIFIED PERSONNEL. NEVER USE ANCHORS AND ANCHOR LOCKING MECHANISMS PRIOR TO PROPER LOCATION OF UNDERGROUND HAZARDS.

FEATURES

1. The LL-2 manually operated load locker is a light duty unit designed especially for use with the Manta Ray MR-3, MR-4, 88-SD, and Duckbill 88 and Duckbill 138 anchors for load locking operations.

2. This unit can also be used to extract anchors that have not been load locked for reuse.

3. The LL-2 weights only 65 pounds and is easily hand carried and operated by one man.

4. The unit can load lock anchors from 55° to 90° from the horizontal.

SPECIFICATIONS

1. Height	30" / 762 mm
2. Width and Length	11" x 28 " / 279 mm x 711 mm
3. Jack Stroke / Stroke with Stem Extended	5 in. / 9 in 127 mm. / 229 mm
4. System Capacity	8000 lbs. / 3632 kgs.
5. Weight	65 lbs. / 29.5 kgs.
6. Shipping Weight	73 lbs. / 33 kgs.

OPERATING INSTRUCTIONS

To operate the LL-2 follow in sequence the instructions listed below. Refer to the PARTS DIAGRAM and PARTS LIST to identify each part.

Anchor Load Locking Procedure

1. A. Anchor rods with threaded end:

   After anchor has been driven to the desired depth, attach appropriate eyenut item 11 (part number EN-58U, EN-16, EN-20) to the screw anchor rod and tighten to snug prosition (or adequate thread engagement). Proceed to step #2.

   B. Anchor rod with integral eye:

   After anchor has been installed to the desired depth, thread rod clamp sling item 11 (part number 0010G02003) through integral eye. Proceed to step #2.

   C. Anchors with cable loop:

   After anchor has been installed to the desired depth proceed to step #2.

2. Lift model LL-2 over the anchor rod (cable end) and place in the optimum pull position. This position will depend upon anchor rod angle, ground slope, and accessibility. The best position is usually with the pull direction toward the jack. See figure 1 below.

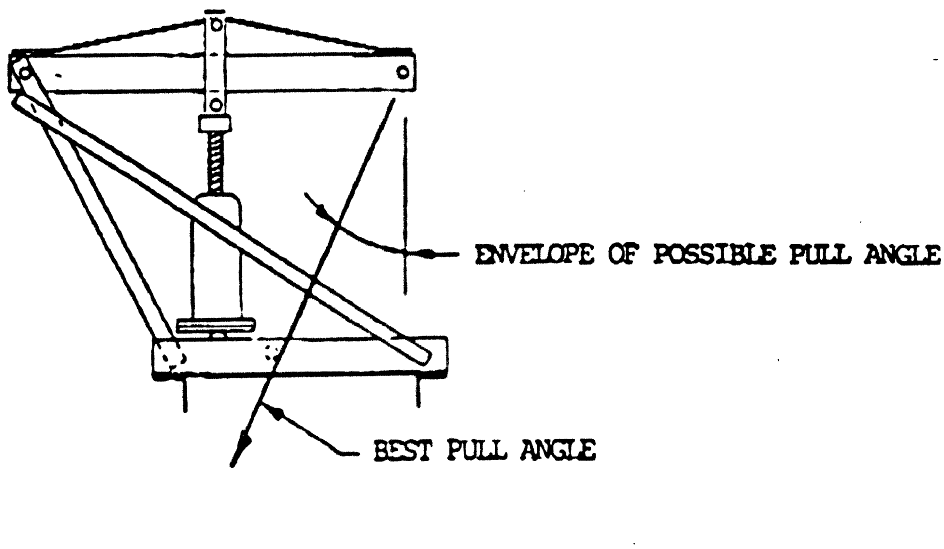


FIGURE 1

3. Release pressure on the jack to remove item 10 (slip hook) from the stored position, then connect item 10 (slip hook) to the appropriate item 11 (part number EN-58U, EN-16, EN-20, 0010G02003). Remove any slack by repositioning item 9 (chain) on item 8 (eye grab hook). For anchors with a cable end loop attach item 10 (slip hook) in loop and position item 9 (chain) on to item 8 (eye grab hook).

4. Close hydraulic valve and begin raising jack.

* * * WARNING * * *
Keep Hands and Feet Clear of Base During All Operations

To assist in speed of operation, the hydraulic jack has an ACME threaded stem for raising item 2 (arm assembly) so that the LL-2 is approximately taut, and a small amount of jacking is required.

5. With all components completely taut observe the stability of the entire system. If the system is skew in an unstable direction, release hydraulic pressure and reposition the LL-2 so as to create a stable stance when load is applied. Repeat step #4.

NOTE:	For extremely soft soil use wood 2x4's placed beneath the heel and toe of the base to increase the base footprint.

6. With continued pumping the gauge will begin to register for the locking operation. Pump jack to the required lock-off load. Note that the pressure gauge will decrease until the anchor is completely turned. When the pressure gauge is constant with continued pumping, the maximum proof load for the turned anchor has been obtained. This maximum proof load is dependant on soil conditions.

* * * WARNING * * *
Do not exceed the rated capacity of the anchor installed. Overloading may cause serious injury. Consult your distributor or Foresight Products for anchor capacity.

7. The gauge pressure to load ratio is a 1 to 1 correlation (ie 1000 psi on gage indicates 1000 pounds on anchor, 3000 psi on gage indicates 3000 pounds on anchor etc., up to a maximum allowable of 8000 pounds on anchor.

Anchor Extraction

1. For anchor rod operations: Before anchor is turned with drive rod still in place, install item 11 rod clamp (part number RC-58U) on the screw anchor rod and tighten as required. Wrap item 11 rod clamp sling (part number 0010G02003) below the rod clamp and between bolts and connect end loops to item 10 slip hook (See figure 2 below). With LL-2 taut pump jack to remove anchor. Reposition the rod clamp on the anchor rod as required to extract the anchor.

2. For cable operations: Before anchor is turned with drive rod still in place, connect end loop of cable through the item 10 (slip hook). With LL-2 taut pump jack to remove anchor. If anchor is too deep for LL-2 to extract when fully extended collapse jack and jack stem and thread cable through item 8 (eye grab hook) or item 10 (slip hook) and install item 11, (2) wire rope clips (WRC-08, WRC-10) to cable and tighten as required. Reposition item 11 (wire rope clips) and continue this procedure until anchor is removed.

* * * WARNING * * *
Do not exceed the rated capacity of the anchor during extraction operations.
Overloading may cause serious injury.
Consult your distributor or Foresight Products for anchor capacity.

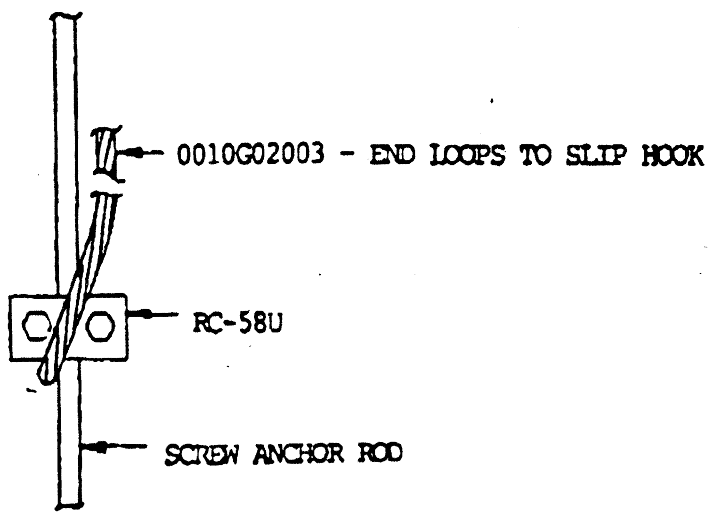
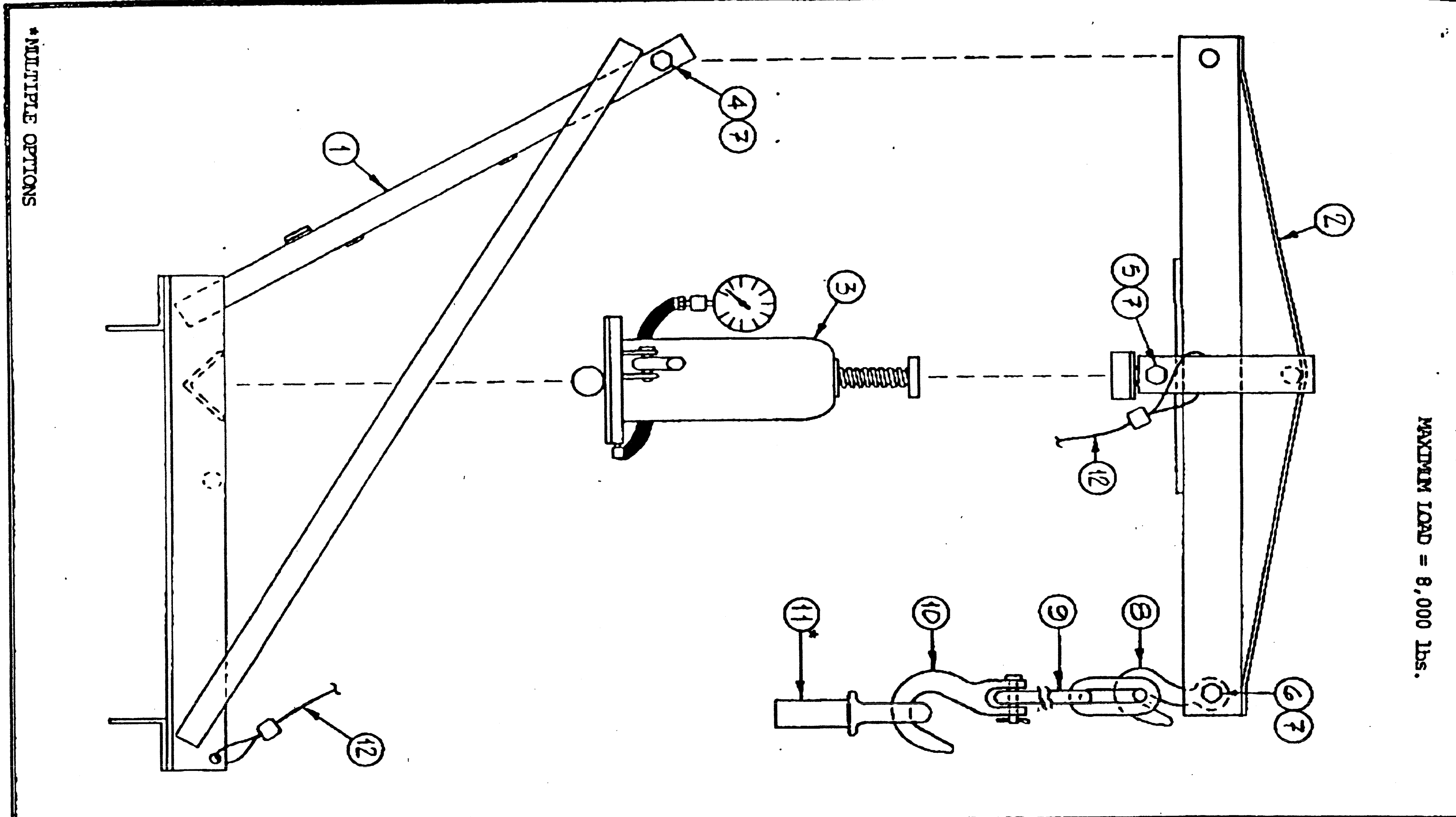


FIGURE 2



FORESIGHT PRODUCTS, INC.
6430 EAST 49TH DRIVE
COMMERCE CITY, CO 80022
303-286-8955 / 303-287-3866 - FAX

PARTS DIAGRAM — LL-2 MEDIUM CAPACITY MANUAL LOAD LOCKER

DESCRIPTION

ITEM	PART NUMBER	DESCRIPTION
1	LL-2B	Base Assembly for LL-2
2	LL-2A	Arm Assembly for LL-2
3	LL-2J	Jack Assembly for LL-2 w/HDL
	LL-2J-1	Hydraulic Jack
	LL-2J-2	Fitting - Jack to Hose
	LL-2J-3	Hose
	LL-2J-4	Fitting - Hose to Gage
	LL-2J-5	Gage
4	B20-5.5-8	Bolt 5/8 - 11 x 5 1/2 GR8 Zinc
5	B20-3.5-8	Bolt 5/8 - 11 x 3 1/2 GR8 Zinc
6	B20-2.5-8	Bolt 5/8 - 11 x 2 3/4 GR8 Zinc
7	NUT-20-Z	Nut - 5/8 UNC (3 required)
8	EGH12HT	Eye Grab Hook 3/8 High Test
9	CHN-10-GHT	Chain 5/16 Galvanized High Test
10	CSH10HT	Clevis Slip Hook - 5/16 High Test
11	TERMINATION ACCESSORIES	
	EN-58U	Eyenut for 5/8" Utility Rod
	EN-20	5/8 Eyenut
	EN-16	1/2 Eyenut
	EXTRACTION ACCESSORIES	
	RC-58U	Rod Clamp for 5/8" Utility Rod
	0010G02003	Rod Clamp Sling
	WRC-08	Wire Rope Clip - 1/4" (2 required)
	WRC-10	Wire Rope Clip - 5/16" (2 required
12	0004G03804	Safety Cable

PARTS LIST - LL-2 MEDIUM CAPACITY MANUAL LOAD LOCKER

DESCRIPTION

FORESIGHT PRODUCTS, INC.
6430 EAST 49TH DRIVE
COMMERCE CITY, CO 80022
303-286-8955 / 303-287-3866 - FAX

WARRANTY

Foresight Products, Inc.'s products are designed to give high quality service and are manufactured from high grade material by competent workmen, under careful supervision. Foresight's manufactured tools and their associated parts are warranted against defects in materials and workmanship for a period of 90 days from the date of purchase.

Foresight reserves the right to repair or replace only those parts which prove to have been defective at the time of purchase.

Ordinary wear and tear, and damage from misuse, neglect or alterations are not covered by these warranties.

DUCKBILL®
PROFESSIONAL
TREE SUPPORT SYSTEMS

DEALER PRICE SHEET
PRICES EFFECTIVE 10/1/93 AND ARE
SUBJECT TO CHANGE WITHOUT NOTICE

GUYING KITS
Completely pre-assembled for strength and to save field labor.

FOR UP TO 3" CALIPER TREES. Kits contain: 3 assembled guylines that include 12' of cable and a DUCKBILL Model 40; 3 protective tree collars; 3 1/16" cable clamps. The kits are packaged in a poly bag suitable for display.

Model #	Type of Cable Used for Guylines	# of Kits Per Case	Shipping Wt. Per Case	Price Per Each Kit
40-DTS	Bare Galvanized Aircraft Cable	12	10#	$10.99
40-DTS- *	Vinyl Coated Aircraft Cable	12	12#	$12.99

*Use "W" for white coating, "O" for orange coating, or "C" for clear coating.

FOR 3" TO 6" CALIPER TREES. Kits contain: 3 fully assembled guylines that include 13' of cable, a DUCKBILL Model 68 and a turnbuckle midline; 3 protective tree collars and 6 1/8" cable clamps. The kits are packaged in a poly bag suitable for display.

Model #	Type of Cable Used For Guylines	# of Kits Per Case	Shipping Wt. Per Case	Price Per Each Kit
68-DTS	Bare Galvanized Aircraft Cable	6	24#	$23.99
68-DTS- *	Vinyl Coated Aircraft Cable	6	26#	$28.99

*Use "W" for white coating, "O" for orange coating, or "C" for clear coating.

FOR 6" TO 10" CALIPER TREES. Kits contain: 3 fully assembled guylines that include 15' of cable, a DUCKBILL Model 88 and a turnbuckle midline; 3 protective tree collars and 6 3/16" cable clamps. The kits are packaged in a poly bag suitable for display.

Model #	Type of Cable Used For Guylines	# of Kits Per Case	Shipping Wt. Per Case	Price Per Each Kit
88-DTS	Bare Galvanized Aircraft Cable	4	30#	$58.99
88-DTS- *	Vinyl Coated Aircraft Cable	4	33#	$64.99

*Use "W" for white coating, "O" for orange coating, or "C" for clear coating.

INDIVIDUAL DUCKBILL EARTH ANCHORS
for contractors who will assemble their own guy system.

MODEL NUMBER		RATED CAPACITY	QUANTITY PER CASE	WEIGHT PER CASE	PRICE PER ANCHOR
40-DB1	Anchor Cabled with 20" of 1/16" Galvanized Aircraft Cable	300 #	50	4 #	$1.69
68-DB1	Anchor Cabled with 2 1/2' of 1/8" Galvanized Aircraft Cable	1,100 #	24	8 #	$3.69
88-DB1	~~Anchor Cabled with 3-1/2' of~~ 1/4" Galvanized Aircraft Cable	3,000 #	12	14 #	$8.99
138-DB1	Anchor Cabled with 5' of 5/16" Galvanized Aircraft Cable	5,000 #	12	37 #	$19.99

(SEE REVERSE SIDE FOR DRIVE RODS)