Development of a Comprehensive Vehicle Instrumentation Package for Monitoring Individual Tripmaking Behavior

Technical Specifications and Analysis

GTI - R - 99003

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1. SYSTEM SPECIFICATIONS -- TECHNICAL ANALYSIS

1.1 Configuration Alternatives Analysis

Several configurations of computer, GPS, engine monitor, and driver interface will be evaluated for potential use in the electronic travel diary. They range from combining the technologies into one package to separating out each unit as a individual component. The figures below give the configuration options, with descriptions, advantages, and disadvantages of each. Each configuration has two setup options, one with the driver interface connected to the computer for data storage, and the other with the driver interface as a stand-alone unit; this option is discussed later in the driver interface section on technologies.

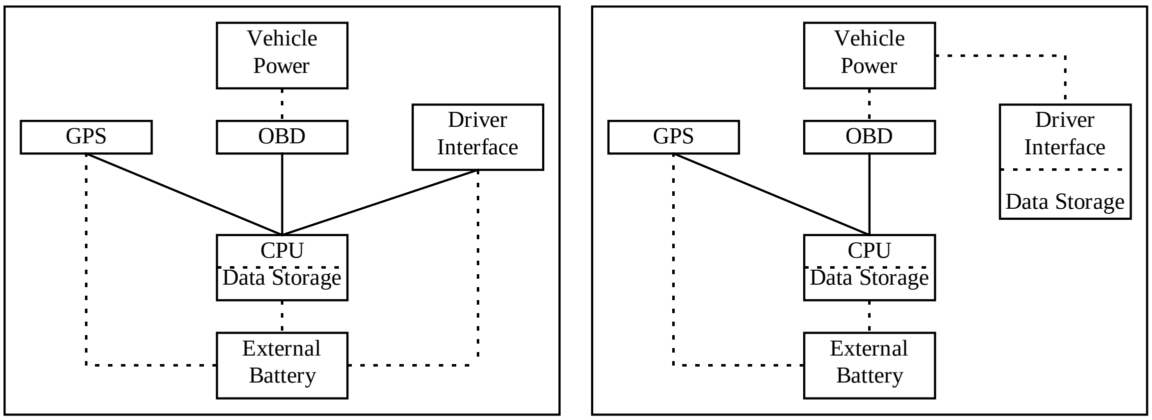


Figure 1 - Separate Components

Figure 1 is the first configuration option, where each component is a separate unit, downloading data to the computer for storage. Given that the GPS downloads position and time in ASCII format, and the driver interface acts like a keyboard, then the OBD data stream could be integrated into the same file to synchronize time stamps. However, the data should be in a format which is understandable by the program or post-processing program. Currently, each data stream is stored in a proprietary binary format, which would require separate files on the computer. Times would not be coordinated, and engine data could be mismatched to spatial location and trip type. In addition, this configuration requires tapping into the vehicle's battery for power to the OBD system and possibly the driver interface.

Advantages
Better components (can optimize individual component performance and functionality)
Increased flexibility in modular design, implementation, and contingency planning

Disadvantages
Additional space and wiring needed
Increased power demand

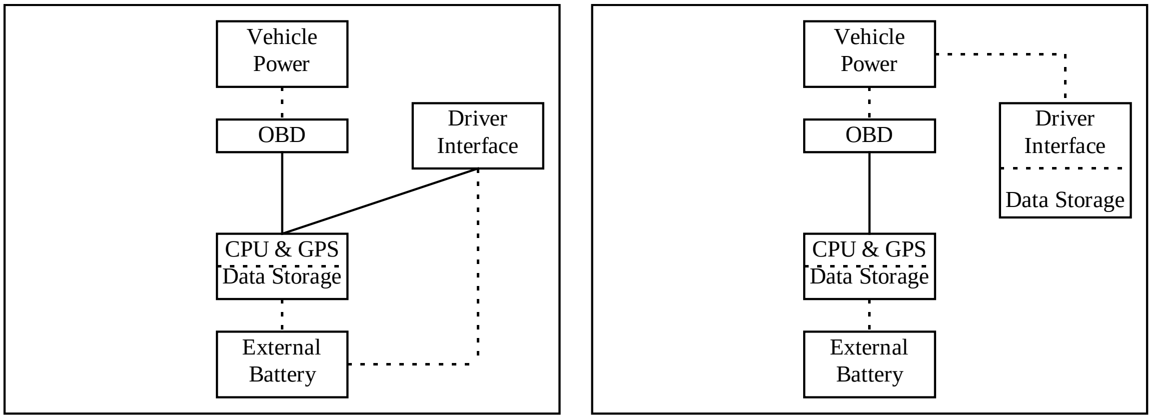


Figure 2 - Integrated Computer and GPS

Figure 2 is an option where the GPS unit is built into the computer unit. Laptop computers can be ordered with this option, or manufacturers offer GPS boards for integration into equipment. With this combination, separate power will not be required for the GPS receiver. However, the data will still have to be captured and stored on the computer.

<u>Advantages</u>

Reduced components and power demand

Reduced cost if buying GPS boards directly and put together

<u>Disadvantages</u>

Higher cost if buying computer with GPS built in

Longer system integration time if buying components to put together

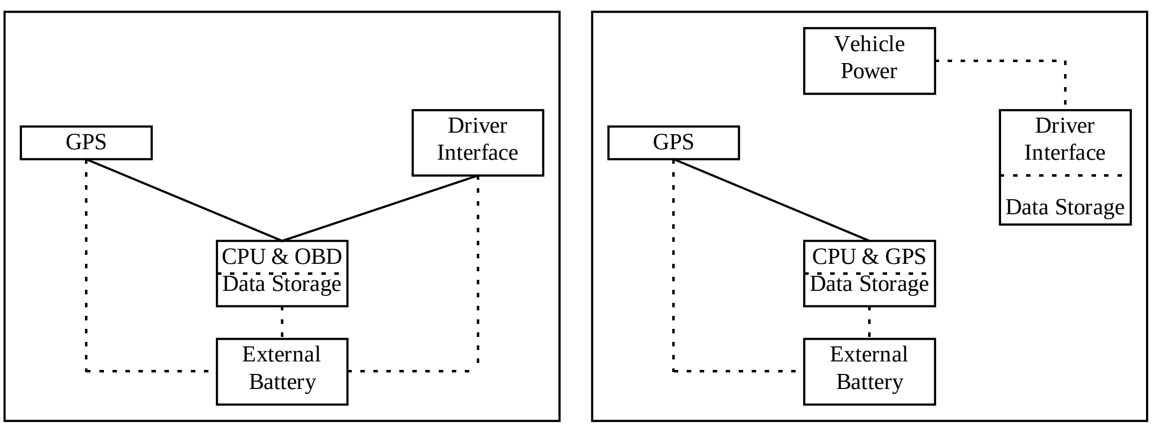


Figure 3 - Integrated Computer and Engine Monitor

Figure 3 is a configuration which combines the CPU and the OBD engine monitor into one package, with an external GPS. This setup is unlikely given available equipment, but an alternate configuration of this would be to store OBD data on a data logger running the OBD software. Time reconciliation and power to data logger would be major obstacles.

<u>Advantages</u>

Reduced components

<u>Disadvantages</u>

No off-the-shelf components available

Higher costs to develop

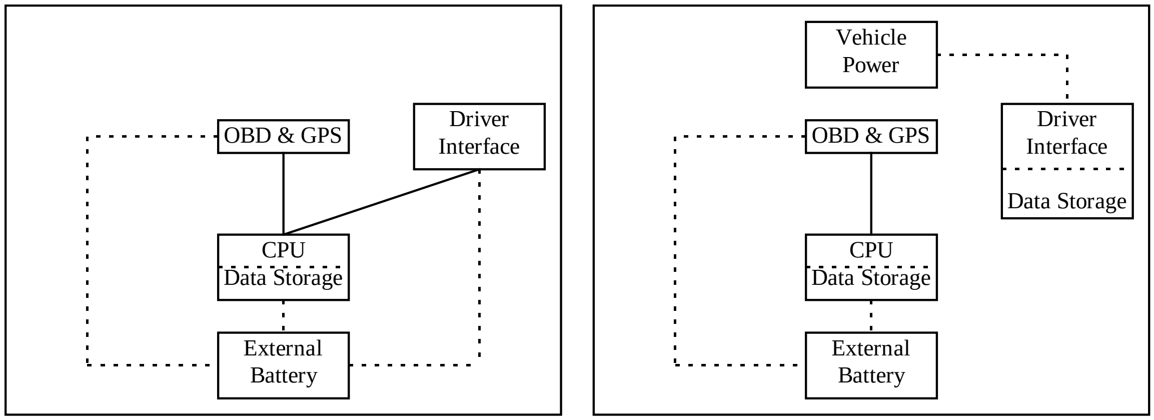


Figure 4 - Integrated Engine Monitor and GPS

The fourth configuration consists of combining the OBD and GPS into one unit, with data storage on the computer (or self contained). Again, this configuration is unlikely given available technologies.

Advantages

Reduced components

Reduced cabling to trunk

Disadvantages

No off-the-shelf components available

Higher costs to develop

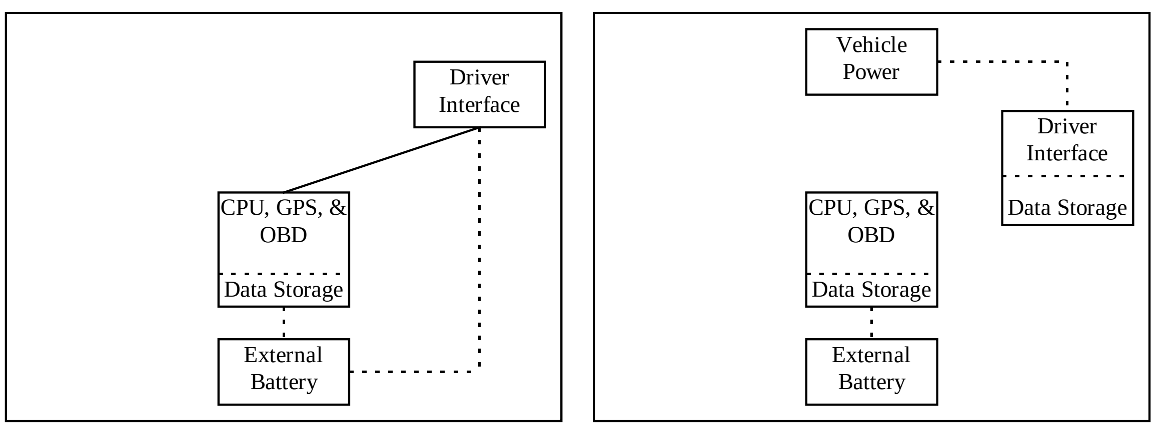


Figure 5 - Integrated Computer, GPS, and Engine Monitor

The final configuration is combining all of the technologies (except the driver interface) into one package and powering off of an external battery. No technologies exist where this would be possible.

Advantages

Portability

Reduced components

Disadvantages

No available equipment

Higher costs to develop

Less flexibility if one component fails

System Configuration – Final Recommendation

The functional specifications for component performance has led to the selection of separate components and thus the first option for the system configuration, with the driver interface as a separate unit as well. Separate components offer the most flexibility and somewhat better performance than integrated solutions. A slight modification has been made to the configuration, however, regarding the power supply. See the figure below for the final recommendation.

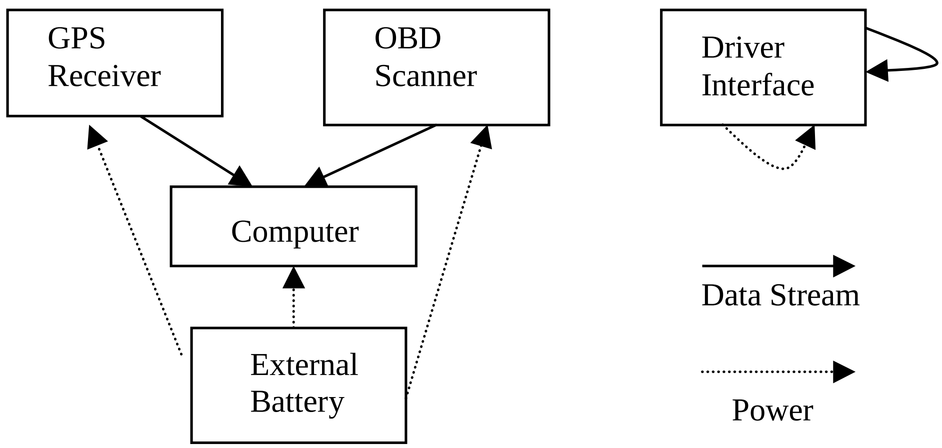


Figure 6 - Separate Components, Driver Device, and External Battery

1.2 Systems Integration

The choice of separate components requires greater effort in hardware and software integration than an integrated solution would, but does offer the greatest flexibility in choice of components. All components chosen are to have serial interfaces to connect to the central CPU, which is used to gather and log the information from each unit with the correct time stamp. It is desirable to have one central program controlling all the components of the system, so each component should have a well defined communications interface not requiring any proprietary software. In the case of proprietary software interfaces to components, the manufacturer's program should be controllable from another application without need of user intervention.

Issues for CPU:

- Number of serial ports
- Hard drive space for data storage
- Power consumption

Issues for control program/operating system:

- Ability to handle multiple serial data streams
- Time stamping/synchronization of data streams
- CPU and component power management

Issues for components:

- Serial command interface
- Update rates
- Power consumption/management

2. INDIVIDUAL COMPONENTS – TECHNICAL ANALYSIS

2.1 Driver Interface

2.1.1 Available Systems

An extensive search was conducted for possible driver interfaces which would operate either as dumb terminals, using the computer of the ETD for program execution and data storage, or as a stand-alone device. The following section includes a representative sample of what is available on the market.

Champion

One programmable keyboard and one display panel from Champion has been ordered and received. The keyboard is programmable, so each keystroke will be recorded with a unique designation. Connection to the computer is via the keyboard cable connection, and also allows series connection with a standard keyboard. The display is a cash register-type display from the same company, but probably not useful for final ETD due to size.

Rockwell

Driver interface packages exist for use in commercial vehicle applications where there is a large market. Rockwell offers the DataTrax driver data terminal which has a one piece integrated keypad and LCD display, along with GPS capabilities geared towards trucking fleets. No information was found on applications targeted towards light-duty vehicles. Most of the other units are point of sale devices, mainly used in commercial applications but can be modified for in-vehicle use.

Phoenix Group

The Vehicle Mobile Data Terminal has a 2-line by 40-character display (or optional 8-line by 32 characters), and a keypad from 20 buttons to a full keyboard at a size of 9.5" W x 4.5" H x 2" D. Other features include a backlit LCD, RS232 interface, and optional GPS. There are no specifications available for the terminal, and sales personnel are not familiar with the equipment. This equipment is manufactured based on specifications from the users, usually in quantities of more than 100.

These are the typical terminals used in rapid accident response data collection and activity reporting.

Telxon PTC-610 (shown with optional pen wand)

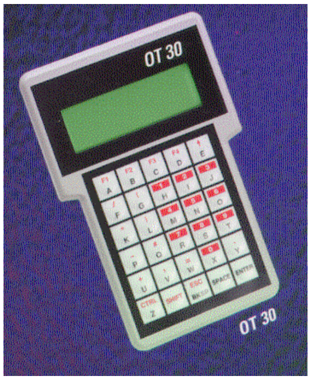
The PTC-610 is a hand-held computer with a 4-line by 16-character display with 35 keys. The unit has a microprocessor, up to 128 KB RAM, and RS232 port. A 24-button keypad is optional on the unit. Cradles are available for recharging batteries in the units, as well as for providing a simple connection to download data. Proprietary software is used to program the unit. No cost data were obtained.

IEE Control Display Unit

The CDU is small and lightweight, with 20 keys and a 4-line by 14-character display. It is designed as a rugged unit to withstand military use. Because of the military specifications of the product, costs are in the range of $5,000. No similar product is manufactured by IEE with a lower cost. Specifications and prices were received directly from the company.

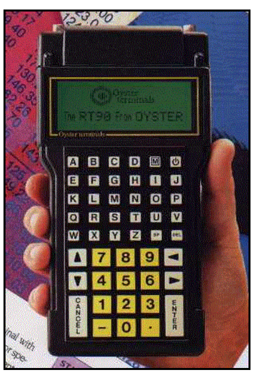
WPI Oyster TermiFlex ST/2000 (formerly OT30)

The OT30 is a hand-held,dumb terminal with a 4-line by 20-character LCD display and a 30-button programmable keyboard with a RS232 interface. Options include 8 by 26 display and electroluminescent backlighting, 5 volt (regulated) or 7 to 24 volt (unregulated) input, with cabling options to computer.



WPI Oyster TermiFlex PT1000

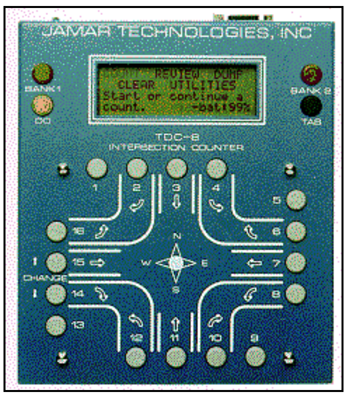
The PT1000 is a programmable terminal with PCMCIA card capabilities. The display is 8-line by 32-characters (4x20 option) and a 48-button keyboard with an internal RS232 port. The handheld is programmed in C or BASIC and has PC programming packages. Programming and data retrieval is done through an integrated RS-232 connection. Fifty hours of use is available between charges of NiCd batteries. The PT1000 is a standalone product compared to the OT30, which is a dumb terminal.



JAMAR TDC-8

The JAMAR TDC-8 Board is a simple electronic data logger with 16 buttons and an integrated 4-line by 20-character LCD display powered by four AA batteries. Printed overlays are available for the keyboard. The current JAMAR configuration provided by the manufacturer is used for field data collection. Researchers currently collect data manually throughout the day and then download the data manually to a computer at the end of the day. The current configuration offers adequate memory for trips made over a one-week period without having to download intermittently. For this project, the driver could turn on the board and enter information, and the data could be saved on the board, along with the time and date. The manufacturer would have to be contacted for assistance in development of an instantaneous data downloading capability, if desired, as well as for the ability to program the boards in-house for custom applications.

If this unit is selected, there would be zero cost to the project since we currently have 22 boards in-house. The true cost of the board is approximately $1000.



Percon PT2000 (shown below with docking station)

The PT2000 is a handheld portable data collection device with a 4-line by 16-character display. The keypad has 34 alphanumeric keys, including four programmable keys. Maximum storage on the unit is 1 Megabyte, with a specified operation range of 12 hours on internal batteries with a 10 day battery backup for data storage in memory. There is a PS/2 interface to allow for use as a keyboard wedge or connection via a RS232 port. Other specifications of the unit include a programmable beeper, real-time clock, automatic shutdown with low batteries, rechargable batteries in unit, and programmability via proprietary software. A docking station is available for the unit which can recharge the unit without having to remove batteries or make any connections. The dock also can connect directly to a desktop computer and allows downloading of all saved data with one keystroke.

Prices for the PT2000 range from $600 with 128K memory to $920 with 1 MB memory. The dock is $150 and software must be purchased to program the unit.

PSION Organiser II

The Organiser is the entry level unit manufactured by Psion. It has different keyboard options. Memory is available by two Datapak ports in the unit, with up to ½ Megabyte of flash memory available for program and data storage. The display can be configured with 2 or 4 lines and has a variable contrast. Programming and communications is completed through the RS232 port.

Prices for the base unit range from $275 to $425, with $450 for ½ MB flash memory. Other accessories to purchase include batteries, battery packs, chargers, communications links, and software.

PSION Workabout (shown below with both keypad options and the in-vehicle cradle)

The Workabout is a rugged hand-held, programmable device with the ability to store up to 16 MB of data on flash memory installed in the machine. Two keypad options are available on the units, a 57-key alphanumeric layout (shown below in cradle) or a 35-key numeric keypad layout (shown below without cradle), which has larger keys. The display is 240x100 pixels, with the ability to display graphics on the LCD screen; 39 characters by 12 lines is the maximum text content. A sound buzzer is included on the unit.

Power is available through internal batteries which can be recharged via a docking station (in trickle or fast charge format). An RS232 port is available for communications. A Vehicle Interface Cradle (VIC) is made to use with the Workabout; it has a dashboard mounting facility, one or three communications ports, and vehicle power conditioning. The VIC also has ignition switch sensing to wake up the Workabout and the ability to recharge the batteries.

The other option with the Workabout is the V-Comm, which incorporates a GPS and vehicle data acquisition (VDA) system into one unit. The VDA detects speed, distance, and 8 voltage or switch sensor inputs. The GPS is Rockwell's Microtracker system with an antenna connected directly to the side of the V-Comm unit. Post-processing differential correction is not possible with this GPS unit.

Prices for the Workabout are $900, and an additional $900 for one 8 MB flash disk (1MB $200, 2MB $280, 4MB $440) with the ability to store two disks in the unit at one time. The VIC is $275, the fast charge dock is $400, and V-Comm with VDA and GPS is $1,360. Software must be purchased to program the unit.

Summary Attributes of Driver Interface Devices

	PGI	Telxon	IEE CDU	OT30	PT1000	JAMAR	Percon	Organiser II	Workabout
Portable or Fixed	fixed	both	fixed	fixed	portable	portable	portable	both	both
Size (LxWxD inches)	8.6 x 3.2 x 1.7	7 x 3.3 x 1.5	3.8 x 5.75 x 1.4	6.4 x 3.9 x 1.6	7.5 x 4.3 x 1.5		7.4 x 2.9 x 1.3		7.4 x 3.6 x 1.4
Keyboard:									
Number of keys	20	35 or 24	20	40	48	16 or 32	34	?	57 or 35
Marking	numeric	alphanumeric	alphanumeric	custom an- dual use	alphanumeric	custom	alphanumeric (dual use)	?	alphanumeric
Back Lighting	yes	no	yes	no	no	no	no	?	no
Display:									
Size	1.4" x 5" 64 x 256 dot	4 x 16	4 x 14	4 x 16 4 x 20	8 x 32 4 x 20	4 x 20	4 x 16	2 or 4 lines	12 x 39 max 240x100 pixels
Character size		5 x 8 dot	5 x 7 dot	5 x 7 dot	5 x 7 dot or double sized	?	?	?	
Type	LCD	LCD	LCD	LCD or backlit LCD	backlit LCD	LCD	LCD	LCD	graphics LCD
Back Lighting	?	controlled contrast	yes	optional	controlled contrast	no	no	controlled contrast	controlled contrast
Graphics in display	no	no	no	no	no	no	no	?	yes
Power Supply	?	internal batt.	5/12 volt	5 / 7-24 volt	battery or 12V	battery	battery	battery, car adapter	battery, dock station
Power Draw	?	?	5mA at 12v w/o backlite	30mA at 5v	?	?	?	?	?
Data Connection	RS232	RS232	RS422	RS232 / 422 / 485	RS232	RS232	RS232 or PS/2 key	RS232	RS232
Operating Temp (°C)	-20 to 70	0 to 49	-40 to 71	0 to 50	0 to 50		-10 to 50		-20 to 60
Memory	256K volatile	Up to 128K	none	64 or 80 characters	up to 512K onboard and 2MB flash memory		128K prog. To 1MB data storage	to .5MB flash mem	to 1MB int. to 16 MB on SSD
Buzzer	yes	?	no	no	?	no	yes	yes	yes
Other			military specs		real-time clock dock station		RT clock scanner Dock station		vehicle cradle, dock station
Cost ($ / unit)	?	?	$5000	$300	$700	$1000	$600	$425	$900
Accessories cost ($)	?	?	?	?	$400	?	$1600	$600	$1400

PGI: Phoenix Group Vehicle Data Terminal
Telxon: Telxon PTC-610
IEE CDU: IEE Control Display Unit
OT30: WPI Oyster OT30
PT1000: WPI Oyster PT1000
Jamar: Jamar Technology TDC-8
Percon: Percon PT2000
Organiser II: Psion Organiser II
Workabout: Psion Workabout

2.1.2 Recommendations

Each device listed above has its own advantages and disadvantages. We will obtain several representative technologies and assess their usefulness in the travel diary package. User friendliness is essential. We will field test with a beta testing group. In addition, risk tradeoffs for equipment damage and loss must be evaluated in conjunction with field tests to identify optimal units. The following paragraph summarizes the four most viable driver interface options.

Initial project specifications called for the driver data to be stored on the ETD's computer, which would make the driver interface a dumb terminal, with a keyboard and display unit combined. Several devices were identified, but were found to be infeasible due to cost (IEE CDU) or were custom manufactured for large quantities only (PGI). One dumb terminal available is the WPI Oyster Termiflex OT30, which has no data storage capability (≈$300).). Other hand-held terminals can be used in this fashion; however, the unit cost will be much higher.

In the stand-alone device category, the WPI Oyster Termiflex PT1000(≈$1100 with accessories) and the Percon PT2000 (≈$2200 with accessories) are both hand-held programmable terminals with many functions which would allow for capture of in-vehicle trips as well as other trips (e.g., walk, bike, transit). And the Psion Workabout is the device with the most options, with storage up to 16 MB, a docking station, and in-vehicle cradles (≈$2300 for unit and accessories). With the in-vehicle cradle, the Psion Workabout could also function transfer data to the ETD computer in real time.

2.2 GPS Unit (with Antenna)

GPS Performance Criteria

Accuracy:	10 meters (maximum deviation)
Update Rate:	minimum every second, configurable to larger intervals
Time to First Fix (cold):	20 seconds (maximum)
Time to First Fix (warm):	20 seconds (maximum)
Reacquisition Time:	2 seconds

Other required features:
- Software trigger for data collection
- Software trigger for power down or battery saver
- RINEX compatible data stream
- No proprietary software to run GPS receiver

Definitions
Accuracy. It has been determined that 10 meters in the maximum deviation allowable for accurate route choice, parking choice, and destination land use classification studies.

Time to First Fix. One primary objective is to capture location immediately upon vehicle startup. If the computer and GPS startup can be triggered by a door-opening detection device, then the system initialization / wake-up process could occur during driver entry into vehicle. This requirement is similar to the OBD data collection requirement for immediate capture of vehicle/engine activity upon vehicle start (key on). We are currently investigating the use of a mercury switch sensor to trigger power-up of units.

RINEX compatible. All data are to be post-processed into a GIS system for analysis and route recovery. The receiver should be able to produce RINEX output (either directly or through software) or include postprocessing software that accepts corrections in RINEX format.

Evaluation Plan
We have decided to focus on two categories of GPS technology: 1) GPS-only technology with postprocessing differential correction (ppdc) capability, and 2) GLONASS+GPS technology. GLONASS+GPS receivers use the Russian global positioning satellites, which are not prone to Selective Availability (SA - position degradation imposed by the U.S. Department of Defense). SA is the major contributor to positional error. If the GLONASS-GPS combination can provide positional accuracy within 10 meters without the need for postprocessing, this would greatly reduce our overall data handling needs. However, if the technology is not capable of meeting this objective, then we will select the best GPS with postprocessing differential correction capabilities. Real-time differential correction is not under consideration due to the limited access of real-time signals in the Atlanta metropolitan region. We will also evaluate dead reckoning devices to assist with the postprocessing of missing GPS data (due to a loss of satellite locks caused by tree canopies or urban canyons).

The following sections contain a brief description of each GPS device initially considered. In addition, a summary table is provided listing all published product specifications. Note that all specifications provided in this document have been given by the manufacturer – it is quite likely that the actual field performance of these GPS units will be very different. Finally, given the high cost of the GLONASS devices, these units will be procured for evaluation only. If the GPS device chosen is one of the two GLONASS-capable devices evaluated, only then will the GLONASS device be purchased.

2.2.1 Available Systems: GPS Only, With Postprocessing Differential Correction

There are numerous vendors producing GPS devices with postprocessing differential correction with accuracy stated to be within 10 meters. The GeoResearch Workhorse was the first product found that met our initial criteria without any modifications.

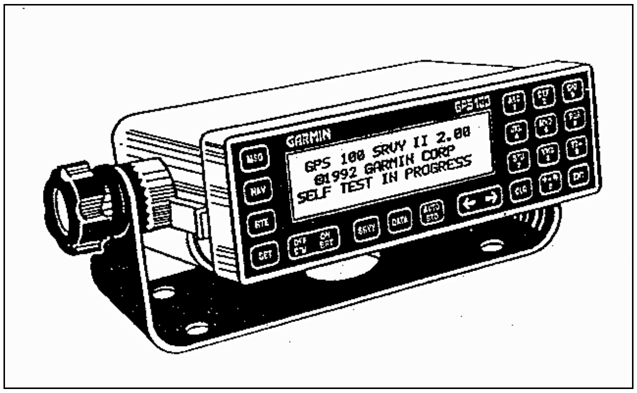
Many of these devices, however, are actually OEM boards. Unless we change our computer specifications to include board capabilities, the OEM boards will not meet our requirements. Several vendors provide these boards inside a casing, similar to a receiver, and call them 'sensors'. We identified several vendors who can provide this product and we are now in the process of selecting the best one for our evaluation phase.

GeoResearch Workhorse

The Workhorse is a GPS receiver manufactured by Ashtech. It has 8 channels and allows for differential correction, either real-time or post-processing. The use of post-processing differential correction yields a position accuracy of 2-5 cm. The time to first-fix in warm mode is 48 seconds, with a typical reacquisition time of 2.5 seconds. It is capable of a 1 point per second output rate, with the option of using NMEA-0183 V2.01 data messages. This unit will also be tested for provision of accurate speed, acceleration, and grade data (given the high accuracy and sampling rate).

The unit has two serial data ports (and can report location to multiple units). These ports provide interface capabilities with external devices, such as a PC.

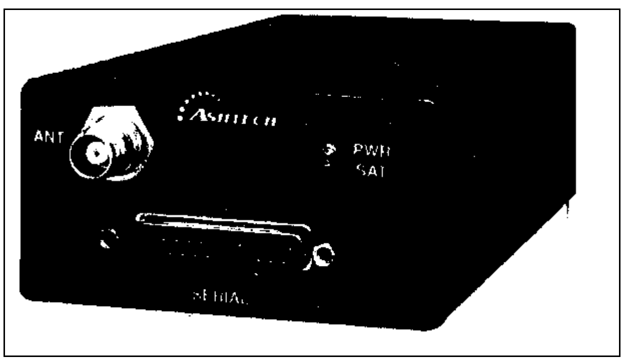
The price for the Workhorse, including the educational discount, is $1,795.



GARMIN SRVY II GPS

The SRVYII is a GPS receiver manufactured by GARMIN. It has 8 channels and allows for differential correction, either real-time or post-processing. The use of post-processing differential correction yields a position accuracy of 1-5 m. The time to first-fix in warm mode is 15 seconds. However, the time to first-fix in cold mode is approximately 2 minutes, which is unacceptable for our specifications. It is capable of a 1 point per second output rate, with the option of using RINEX or NMEA-0183 V2.01 data output.

The unit has two serial data ports. These ports provide interface capabilities with external devices. Price for the SRVYII is $2,995, plus $46 for a magnetic mount antenna, carrying case and AA battery pack.



Ashtech Super C/A Sensor

The Super C/A Sensor is a GPS receiver manufactured by Ashtech. It has 12 channels and allows for differential correction, either real-time or post-processing. The use of post-processing differential correction yields a position accuracy of 1 cm +-1ppm. The time to first-fix is typically less than 1 minute. It is capable of a 1 point per second output rate, using NMEA-0183 data output format.

The unit has three serial data ports. These ports provide interface capabilities with external devices. Price for the Super C/A is $3900.

<u>Ashtech Super G12 Sensor</u>

The Super G12 Sensor is a GPS receiver manufactured by Ashtech. It has 12 channels and allows for differential correction, either real-time(rt) or post-processing(ppd). The use of ppd correction yields a position accuracy of 90 cm. It has a variable output capability, which varies from 1Hz to 8.25MHz, using NMEA-0183 data output format. No information regarding time to first start was provided for this unit.

The unit has two serial data ports. These ports provide interface capabilities with external devices.

Price for the Super C/A is $2850.

2.2.2 Available Systems: GLONASS CAPABLE

There are only two vendors in the market currently providing commercial GLONASS+GPS devices – Ashtech and 3S. Both vendors have agreed to provide us with an evaluation system during our testing phase. These systems will be on loan for 30 to 45 days and will be obtained as soon as the GPS test plans are complete.

<u>Ashtech GG24 Sensor</u>

The GG24 is a combined GPS-GLONASS receiver manufactured by Ashtech. It has 12 channels for L1 GPS and 12 channels for L1 GLONASS, providing all-in-view tracking for both constellations. The use of both satellite systems allows the receiver to have a position accuracy of 16 meters in autonomous mode. The time to first-fix in warm mode is 30 seconds, with a reacquisition time of 2 seconds. The unit is capable of a 2Hz output rate, using NMEA-0183 V2.01 data output.

The unit has three serial ports. External control can be provided by an external PC using one of these ports. It includes PC software for visual display of satellite information, receiver position and velocity, besides providing communication with the receiver.

List price for the GG24 is $9250, plus $90 for a magnetic mount antenna. With a 40% educational discount, this price is reduced to $5640.

3S GNSS-300

The GNSS-300 is a combined GPS-GLONASS receiver manufactured by 3S. It has 12 channels, each of them can be assigned to either GPS or GLONASS satellites. The use of both satellite systems allows the receiver to have a position accuracy of 10 meters, regardless of Selective Availability Status.

The time to first-fix in warm mode is 30 seconds, with a reacquisition time of 10 seconds. It is capable of a 1 point per second output rate, using NEMMA data messages.

The unit has two serial and one parallel data ports. External control can be provided by an external PC using one of these ports. It also includes an internal PC/AT host computer and navigational software.

List price for the GNSS-300 is $8,900 -- with a 25% educational discount the price is $6675. Additional quantity-based discounts are available.

Vendors Considered:	**GeoResearch**	**GARMIN**	**Ashtech**	**Ashtech**	**Ashtech**	**3S Navigation**
Product Evaluated:	Workhorse	SRVY II GPS	Super C/A Sensor	G12 Sensor	GG24 Sensor	GNSS-300
(config. w/ accessories)	Magnetic Mount GPS Antenna w/ 6m cable	MagneticMount Antenna Kit	Marine IV Antenna w/ 10m cable	Choice of Antenna (Marine IV or Aircraft)	Choice of Antenna (low profile marine IV w/ Mag Mount)	RHCP patch antenna
	Data Power Cable	Power/data cables	Power / I/O Cables	Sensor DB25 Connector		Internal PC/AT 486 host computer
	Veh Power Adptr	PC software kit		Evaluate SW & manual	Evaluate SW & manual	Remote control and display software
	Carrying Case	Carrying Case				
	3 AH external 12vdc batt/chrgr	Rech battery pack, 115/230VAC battery charger		Choice of power supply and accessories	Choice of power supply and access.	110/220 VAC power converter
		AA battery pack				
Cost:	$1795 Receiver	~ $2500	$3900	$2850	$5550	$6675
	$350 pp software				$90 Mag Mount	
	$900 rt software					
Features:						
Data Collection Activation / Deactivation					Power on/off or terminal command	Can be controlled by external PC
Number of Channels	8	8	12	12	24 (w/ Glonass)	12
Acquisition Times:			‘ < 1 minute ’			
Warm	22 seconds	15 seconds			30 seconds	30 seconds
Cold	48 seconds	120 seconds			40 seconds	12.5 minutes
Re-acquire	2.5 seconds			‘less than 2 seconds’	2 seconds	10 seconds
Update Rate		1/sec, continuous	1/sec	Config up to 10 Hz	Config up to 5Hz	1 Hz
Data Accuracy:						
Position:	25 meters, SEP (*+100m)	15 meters NAV mode (* +100m)	25 meters, SEP (*+100m)		16 meters, autonomous	10 meters
		5 m / avg *				
		3-10 m / rt DGPS	1 m / rt DGPS	90 cm / rt DGPS	75 cm w/ rt DGPS	
		1-5 m / pp DGPS	1 cm / pp DGPS			

Vendors Considered:	**GeoResearch**	**GARMIN**	**Ashtech SC/A**	**Ashtech G12**	**Ashtech GG24**	**3S GNSS-300**
Velocity:		0.1 knot RMS	1cm/sec, .02 knots		.3 knots (95%)	.1 m/sec
Data Storage Capacity		50 hours of 3D position data	Optional 4 mb memory board		None	
Realtime Diff Corr (RTCM)	Yes		Yes	Yes, RTCM V2.1	Yes	Yes
Postprocessing DC Software	Yes, GeoLink	Yes	Yes, optional with L1 Carrier Phase		No	No
Compatible w/ ?						
Base Station (RINEX)					Yes	Yes
BaseMaps						
Map Matching Software						
Antenna Active/Passive	Accepts both					4” diameter, 4” deep
Antenna Mounts	(Mag Mount)					(Mag Mount)
Size	3.25”x2”x0.6”	6.25”x3.95”x2”	3.65”x1.9”x6.2”	95mm x 42 mm x 168mm	172mm x 58mm x 225mm	75mm x 178mm x 250mm
Weight	19 oz.	25 oz. Incl batpack		19 oz.	3.4 pounds	2.0 kg receiver 0.8 kg antenna
Case	High impact, rugged	High impact plastic, water resistant			Water resistant	
Temp Range (operating)	-30 to 85^{o}C	-15 to 70^{o}C	-20 to 55^{o}C	-30 to 60^{o}C	-30 to 55^{o}C	0 to 50^{o}C, 95% humidity
(*with onboard battery)	-20 to 60^{o}C *					
Power Source(s)	3 AH external 12vdc battery and charger	Rechargeable NiCad battery pack		110/220 power supply and cables	110/220 power supply and cables	
	Cigarette Adapter Lithium Battery	Alkaline (6AA) Battery pack		Cigarette Adapter	Cigarette Adapter	
		10-33VDC or 115/230VAC		Spade connector & cables (fuse)	Spade connector & cables (fuse)	

Vendors Considered:	**GeoResearch**	**GARMIN**	**Ashtech SC/A**	**Ashtech G12**	**Ashtech GG24**	**3S GNSS-300**
Power Draw:						
Battery Saver:	60uA max	155mA				
Normal Mode:	230mA at 5V	245mA	4W	2.1W (rec & antenna)	2.9W (rec&ant)	22W@12VDC
	275mA at 5.25V					
Operating Voltage	4.75-5.25VDC		6-15 VDC	9-36VDC	6-15 VDC	9-18 VDC
Standby Voltage	2.5-5 VDC					
Continuous Operation						
AA battery pack		8 hours				
NiCad battery pack		5 hours				
(battery saver increases time approx. 50%)						
Interfaces:	NMEA0813 V2.00	NMEA0180,0182, 0183,SURVEY, RINEX, RS-232	NMEA0183	NMEA0183 V2.01	NMEA0183 V2.01	NMEA0183 and RINEX
	2 serial ports		3 RS232 I/O ports (38,400 baud)	2 bi-direct RS232 ports, up to 115,000 bps	3 RS232 ser ports up to 115,000 bps	2 serial and one parallel port

2.3

2.3 On Board Engine Monitoring System (OBD)

The research team is currently evaluating two OBD systems. Technical descriptions are provided below.

2.3.1 OTC Monitoring System

Startup:
This monitoring unit does not have a power switch. It is powered up upon connection to the test vehicle. Once the unit is powered up, if the test vehicle has not been started, the monitor will prompt the user to start the vehicle. Similar to the SNAP-ON scanner, upon startup, the user must key enter answers to a series of questions, including make, year, and model of the vehicle and other setup questions. Once these steps are complete, a check is made for connectivity to the vehicle's engine computer. The monitor then begins receiving vehicle data, which appears on the scanner screen and is updated each second (or every three seconds). A scroll feature on the scanner allows for viewing of different engine parameters displaying either four or six of the parameters at once.

Operating Mode:
A recording feature will allow user to record 60 frames of data; 30 frames prior and 30 frames after pressing the record button. The unit does not provide any mean of remote interface control with personal computer systems. However, a RS-232 serial port is available for connecting to VT-100 type terminal.

Shutdown:
The shut down procedure is manual. Unit can not be powered up or shut down remotely.

Monitor Module and Connectors
Connectors are provided which attach to the vehicle's engine control computer. Separate modules which are plug-ins to the monitor unit are provided for US manufactures, (GM, Ford, and Chrysler) as well as for Asian manufactures and generic OBD-II compliant vehicles.

2.3.2 SNAP-ON Scanner

Startup:
The scanner unit itself must be turned on after the vehicle has been started, otherwise the scanner will prompt the user to start the vehicle first. Upon scanner startup, the user must key enter answers to a series of questions, including vehicle identification (same as last time or, if not, then the user must enter VIN) and other setup questions. Once these steps are complete, a check is made for connectivity to the vehicle's computer. The scanner then begins receiving vehicle data, which appears on the scanner screen and is updated each second. A scroll feature on the scanner allows for viewing of different vehicle and engine parameters. Then, the PC software is manually initiated from DOS, a filename is entered, communication links to the scanner are verified, and the PC begins to receive and store data from the scanner for each second. This data is stored in binary format and the PC's date and time stamp is used for the file.

Operating Mode:
Current PC software to capture the data allows the program to run for 30 minutes before having to exit the program and save the file to the hard disk. Thus, an operator must monitor the software to stop the data collection process and save the file. Once the file is saved, the program can be restarted and an additional 30 minute period started. Meanwhile, the scanner itself continues to report data as long as it has power and the vehicle is on. ECM will modify the software functionality to provide unlimited data recording of all monitored parameters.

Shutdown:
The shut down procedure is manual. Termination of data storage can be initiated from the PC at any time within the 30 minute collection period. It is assumed that if the Snap-On loses power, then the data storage is also terminated and that if the vehicle is powered off, both the monitor and the PC processes are terminated (these events needed to be verified). The ECM staff are currently determining whether automated file recording can be accommodated in the program.

Postprocessing
After the data have been captured and the collecting program terminated, a second program must be initiated on the PC to convert the binary format into ASCII in a post-processing step. Also at this time, the user must specify the six variables to be written to the ASCII file. The research team has a program which will take an input file listing all variables needed and run the data conversion program the appropriate number of times in order to convert all fields desired.

Scanner Modules and Connectors

Connectors are provided which attach to the vehicle's engine control computer. Separate modules (which are plug-ins to the Snap-On Unit) are provided for each of the three US manufacturers (Ford, Chrysler, and GM), as well as for Asian and European manufacturers. Module updates are available on a yearly basis as new model years are released. Each update contains information for all previous model years for that manufacturer as well. It is important to note that each manufacturer-model year combination may capture a different subset of the maximum of 70 variables mentioned previously. A range of 20 to 40 variables has been seen within the data captured for the US manufacturers, with more variables available for more recent model years.

Below is a list of the variables available for a "1991 CHEVROL 3.1L V6 CHEVY PFI" -- name obtained from output file.

```
 1) RPM               2) O2(mV)            3) INTEGRATR
 4) OPEN/CLSD LOOP    5) EXHAUST OXYGEN    6) TPS(V)
 7) THROTTLE(%)       8) BLOCK LEARN       9) BLM CELL
10) IDLE AIR CONTRL  11) O2 CROSSCOUNTS   12) BASE PW(mS)
13) CCP DUTY CYCLE   14) TIME             15) A/F RATIO
16) SPARK ADV(ø)     17) DESIRED IDLE     18) START CLNT(øC)
19) CAT CONV(øC)     20) COOLANT(øC)      21) MAT(øC)
22) MAP(kPa)         23) MAP(V)           24) BARO(kPa)
25) BARO(V)          26) KNOCK            27) KNOCK RETARD(ø)
28) EGR SOLENOID 1   29) EGR SOLENOID 2   30) EGR SOLENOID 3
31) CCP DUTY CYCLE   32) BATTERY(V)       33) FUEL PUMP(V)
34) HIGH BATTERY     35) CRANKING RPM     36) PROM ID
37) TIME             38) HEATED WINDSHLD  39) A/C REQUEST
40) A/C CLUTCH       41) LOW A/C PRESS    42) HI PS PRESSURE
43) VEH SPEED(KPH)   44) 2ND GEAR         45) 3RD GEAR
46) 4TH GEAR         47) TCC COMMAND
```

Note: our enhanced air quality model development (MEASURE) requires new algorithms for:
1) Gearing
2) Throttle Position Dither
3) Catalyst Warm-up Time
4) A/C Operation and Parameters
5) Enrichment Triggers (currently developed from RSD and lab tests)

2.3.3 OBD Recommendations

The project team will proceed with the testing phase of the project using the OTC scanner and accessories. No further research will be conducted for the SnapOn scanner until modifications are made to the system by the vendor that will allow it to be easily integrated into the ETD system. In addition, the research team is looking into PCMCIA card options for OBD II vehicles. (A copy of our enhancement request list sent to the SnapOn development team can be seen on the following page.)

2.3.4 Snap-On Enhancements Request

Below is a copy of the requirements reviewed with Snap-On in November. No work has been initiated to date.

TO: Ron Patrick November 17, 1997
FR: Georgia Tech
RE: List of Enhancements -- Snap-on Scanner

As we discussed in our last meeting regarding the required functionality of our Instrumented Vehicle Package, also referred to as the Electronic Travel Diary, there are several modifications / enhancements needed to the existing Snap-On Scanner functionality. This instrumentation package will be installed in private vehicles and will capture data for a period of seven to ten consecutive days. Components of the package include:

CPU	Driver Interface
OBD Computer Monitoring System	Power Supply
GPS with Antenna	Other Sensor Devices

Below is a list of topics for our phone call with you and your colleagues tomorrow.

Functionality Needs:

- Start up must be automated (no manual input needed for software or device) and should not be dependent upon ignition start (see startup process below) e.g. car door sensor. The SNAP-ON should query for a new vehicle and data collection parameters at the end of a data collection cycle, to remove front-end dead time (it will be on same vehicle for long periods)
- Start-up should be as quick as possible, perhaps 5 to 10 seconds.
- Shut down should be soft --provide sleep mode for OBD in order to conserve power demand
- Must be able to capture data continuously without limit on time duration (current limit is 30 minutes)
- Software must allow for simultaneous capture and storage of up to five additional data streams (including other sensor-type devices)
- The CPU's date and time stamp should be used for all records
- The GPS, driver interface, and other sensor inputs should be fed directly into the Snap-On data stream, time stamped with the CPU clock (as is currently done)
- Must have an automated error detection and correction / reboot process to ensure continued data collection
- Must have feedback to driver interface to signal SYSTEM DOWN, to enable correction of problem.
- Finer resolution than integer mph (is it possible or is it determined by vehicle?)
- Capture interval configurable from 1 to n seconds to help reduce storage requirements. For intervals larger than 1 second, we need the option to select the average over the interval OR the value at second n for each parameter in the time period.
- If data storage becomes an issue, then capture only those variables pre-selected in order to reduce storage requirements (need to work out data storage issues first, then can determine if this option is needed).
- Post-processing: The program SGC.EXE (which converts binary to ASCII) should extract as many variables as we want for a single run (now limited to 6 variables per run)

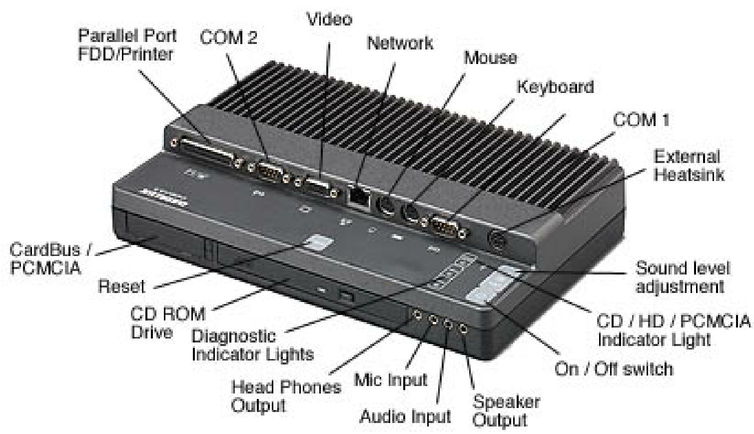
Questions:

- Do we want one binary file for entire test period? If so, should it be closed/saved upon each vehicle shut down and then appended upon vehicle activation? If not, then how should the individual files be tagged / named?
- Has anyone assessed the impact of Snap-On Scanner's operation on the variables being measured? Examples include the power draw from the lighter and the OBD's monitoring priority as compared to other system requirements being managed by the vehicle's computer system.
- What are the options for power supply for the Snap-On Scanner and CPU?

2.4 Computer / CPU / Software

2.4.1 Computer

A ruggedized computer running off of 12 volt DC power is required to control the ETD. The unit needs serial ports, hard drive storage, and expandability (whether internal cards or PCMCIA slots) to gather and log the data from the individual components while having minimum power draw. For this task some type of laptop computer or battery powered industrial computer will be necessary. During the test the computer will be in the trunk of the vehicle and there will be no need for a screen or keyboard once the unit is setup. The only computer identified that meets these requirements is the Datalux Databrick. It is a rugged, DC powered, compact industrial computer with a removable screen and keyboard. The Databrick was initially based on the 486-class processor, but that model has been discontinued and replaced by the Pentium class Databrick II.



Features of the Databrick II:

- Pentium processor, 150 MHz and higher
- Internal CD-ROM
- Internal 2.5" hard drive
- 2 Type 2 PCMCIA slots
- Thermal management: case has large cooling fins, CPU speed is reduced to lower heat output
- Power management: CPU speed reduction, hard drive spin down, suspend mode
- DC-DC converter: runs unit on 8-16 Volt DC power
- 2 RS-232 ports
- Built-in VGA video
- Compact size: 2" H x 10.25"L x 6.5"W

2.4.2 Software

The major software components to be used are the operating system for the computer and the application program controlling the various components of the ETD. The Windows 95 operating system was installed on the Databrick II. This is currently the standard operating system for Pentium class computers and the one in which most applications currently run. Window 95 also supports multitasking, power management and PCMCIA slots.

The application development environment selected for the ETD is National Instruments LabVIEW. This is a graphical programming environment designed to support development of instrument interfaces as well as supporting data acquisition hardware such as A/D cards and digital interface cards. LabVIEW has multitasking features which should help distribute the load of reading multiple components continuously. We have also purchased Application Builder which allows stand-alone executables to be created from LabVIEW programs.

2.5 Temperature / Relative Humidity Sensor

Data loggers have been ordered and received from Onset Computer Corporation. The devices are small, self-contained units that log temperature and relative humidity at intervals specified by the user. The temperature devices have external temperature probes that can be used. One device, the Stowaway, can store 32,500 readings. Thus, the minimum time between readings for a full seven-day data collection process is one temperature measurement every 30 seconds. The HOBO logger can store four different variables, including humidity, temperature with and without the probe. With all four variables selected for capture, the minimum time between readings would be five minutes, and could be reduced by limiting the number of variables to temperature and/or humidity.

2.6 Solar Load (Light Intensity) Sensor

One device has been received from Onset Computer Corporation, the HOBO LI. This device measures from 0.01 to 15,000 lumens/ft^2. Another logger also measures light intensity (along with temperature, external, and RH) but it only measures up to 1,000 lumens/sf, which is not sufficient for measuring sunlight intensity. The HOBO LI will store a measurement once every 5 minutes for a 7 day period before filling the memory.

2.7 Other Sensor Devices

Additional sensors will be identified and evaluated as necessary. Possible sensors needed include:

- Driver door opening
- A/C Load
- Catalyst temperature
- Tailpipe emission concentrations and rates

2.8 Power Supply

Several terms are used throughout battery literature, and should be defined:

- Amp-hour is the most common battery rating. It is a unit of measurement for battery capacity, obtained by multiplying the current flow in amperes by the time in hours of discharge. The amp-hour rating on the battery has little significance unless qualified by the number of hours the battery is discharged, usually rated for 20 hours, but varies by manufacturer. The amp-hour rating is only a general method of evaluating a battery's capacity for selection purposes.
- Reserve capacity, which is the number of minutes a battery can maintain a useful voltage under a 25 ampere discharge.
- Cold cranking amperage (CCA) is the maximum amperes that can be continuously removed from a battery for 30 seconds at 0°F, a useful measure only for engine starting batteries.
- Cycle life is the total number of cycles (total discharge from a full charge, and return to full charge) a battery can perform before failure. This is often a non-linear relationship, as the number of cycles increases the ability to provide full power decreases.
- Deep cycle is a term given to batteries designed for continuous discharge and charging without losing its capacity. Deep cycle batteries will perform well as cranking batteries, however, cranking batteries will not survive deep cycle use.

Capacity of a given battery is dictated by several physical and operational characteristics of the battery. Increase in capacity of a battery can be achieved through increasing volume and plate area of battery and preventing damage from over discharging. Decrease in capacity will occur if the temperature becomes low, the rate of discharge increases through excessive cycling, age, over-charging, or under-charging of the battery.

The state of the charge can be changed by connection of two or more batteries together. In a series connection, batteries of like voltage and amp-hour capacity are connected to increase the voltage of the bank. The positive terminal of the first battery is connected to the negative terminal of the second, and so on. Final voltage is the sum of all voltages added together, while final amp-hours remain unchanged. In a parallel connection, positive terminals of all batteries are connected together, and all negative terminals connected in the same manner. Final voltage remains unchanged, but the amp-hours is the sum of the capacities of the individual batteries of this connection.

Estimated current draw is important for determining the size of battery needed, whether for full 7 days (168 hours), or for only operation without engine on (72 hours between recharging). With an average trip time of 13.2 minutes at 6.3 miles (Atlanta average from 3-parameter database study), the engine-on time does not appear to provide the amount of time necessary to fully charge batteries.

Referring to the Component Test Plans/System Integration Test Plan document a reasonable estimate for total current draw on the battery is 2.1 amps. Actual draw may be less depending on how often the computer is required to write data, operate hard drive, and the extent to which power saving occurs.

2.8.1 Choosing battery capacity

Several sources were found on specifying battery capacity. The first source chose to de-rate the battery for capacity tolerance, temperature, and discharge rate, with the 40% increase in capacity based on "worn-out" batteries. [cite sources here]. The other method ("second method") uses a conservative approach of doubling required capacity and matching the figure to the 20 AH rating of a battery. Both methods are conservative approaches to sizing.

Battery only (7 days):

168 hours @ 2.1 amps	353 AH
15% capacity loss, tolerance	53 AH
Cold temperature adjustment	0 AH
Time period adjustment	0 AH
40% economic life cycle	141 AH

Total capacity of battery needed is 547 AH battery, under the second method a 705 AH battery would be required.

Battery/Alternator (3 days):

72 hours @ 2.1 amps	151 AH
15% capacity loss, tolerance	23 AH
Cold temperature adjustment	0 AH
Time period adjustment	0 AH
40% economic life cycle	60 AH

Total capacity of battery needed is 234 AH battery, under the second method a 302 AH battery would be required.

2.8.2 Battery only configuration

In this configuration, all equipment would be powered by gel cell batteries placed in the trunk of the vehicle. In order to achieve the necessary power, two batteries are required. They can be 6V cells in series or 12V cells in parallel. The trade-off in selection of cells is weight/cost versus backup amperage. Some example setups are, where two batteries would be required are:

Type	*Amps, each*	*Volts, each*	*Wt, each*
Lifeline 8D	255	12	158
SEC 12-260G	260	12	161
Rolls 12HHG-8D	275	12	183
Rolls 12CH-15P	370	12	257
Rolls 6-33P	625/846	6	264/310

[Please add cost and dimensions to the table]

2.8.3 Battery with automotive charging

In this system, a smaller battery would be used to power equipment, and be recharged when the car is running. Typical battery size would be similar to those in the table above, only with one battery needed in the application. It would provide more than three days worth of power before recharging is required.

Recharging deep cycle batteries from the automobile charges at a rate equal to the total output of the source. Alternators put out between 35 and 200 amperes, with most newer vehicles towards the higher end. If a 100 ampere deep-cycle battery is being charged with a 55 amp alternator, the rate is over 5 times faster than it should be charged, which could cause premature battery failure and lower system efficiency.

The voltage regulator on the alternator does not work well for deep cycle batteries. Of course, this type of system works extremely well for starting batteries which is cycled to less than 1% of its capacity before being refilled. However, deep cycles are almost empty when recharged. The voltage from the car attempts to instantly bring the voltage to 14 volts, which is not achieved until the battery is full. The result is too much energy too fast for a fully discharged battery. In addition, voltage needs to reach 16V for putting a full charge, which the alternator is not capable of achieving. Deep cycle batteries typically need 24 hours of recharge (if fully depleted) to obtain full capacity.

2.8.4 Recommendations

Based on problems associated with charging deep cycle batteries from the car's power, it is recommended to provide power for all accessories from stand alone batteries. Actual amp-hr power needed may be less than stated previously, depending on actual computer use and LCD power use (but could also be more). The recommended amp-hr battery size for the configuration is 547 by one estimate and 700 with the other. Achieving these values is only possible through 2 (or more) batteries.

Being slightly less conservative, two Lifeline 8D batteries in parallel connection would provide 510 amp-hrs at 12V. Additional weight of the two batteries is 158 pounds each, for a total of 316 pounds. Sizes are 21x11x10 inches for each. Costs of $325 for each battery were obtained from DC Battery Specialists; chargers would also need to be ordered to match the size of the battery.

The other option is to provide shut-down of equipment when not in use. Given that a vehicle may only be operated 2 to 4 hours per day, it may not be necessary to provide power for a full 24 hour day. This would greatly reduce the size of batteries required. And if the diary was placed in a vehicle which is driven extensively (where this information is gathered from the pre-survey interview), additional batteries could be added when appropriate.

2.9 Power Surge Protection

If the ETD is powered from its own batteries, the power should be clean and constant until the battery nears the end of its charge when the voltage will begin to drop. Most of the components being considered have been designed with 12V DC automobile power in mind and thus use DC-DC converters that can handle voltages between 8 and 16 Volts DC and still provide regulated power for the component.

2.10 Noise Suppression

Components near the engine will be shielded to minimize the effects of electrical noise from the vehicle's ignition system. Cables interconnecting the components of the ETD will be shielded to minimize noise problems in data transmission. If the ETD is connected to vehicle power, noise suppression in the power supply line may be necessary to filter out alternator and ignition noise in the power line.

2.11 Cooling Mechanism

The Databrick II is equipped with large, metal cooling fins to dissipate heat, which are more effective with a forced cooling airflow. The box containing the ETD will be vented. If it is determined that more than ambient convection is necessary some type of fans will need to be installed to cool the box. This provides an increased power draw and alternate power sources for the cooling fans should be investigated such as solar powered fans assuming that when the sun is out to power the cooling fans it is also providing the greatest heat loading to the vehicle.

2.12 Security Devices

Theft deterrents, including nondescript casing and truck-mount antenna, will be considered to improve system and vehicle security. Other security devices may also be evaluated, including the Lojack System, which is used by the police to recovery stolen vehicles.

2.13 Mounting / Vibration Mitigation

Fixed mounting or straps (nylon or velcro) will be evaluated to limit system movement and vibration.