APPENDIX D - SYSTEM OVERVIEW

LocatorNet℠ System Overview

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Abstract
LocatorNet^SM is a network-centric location and processing system optimized to deliver location services to third party service providers. The LocatorNet^SM architecture can support multiple communication links. The LocatorNet^SM architecture can also support multiple devices. LocatorNet^SM is technically advanced, highly-mature, and completely customizable by NAVSYS/LocatorNet^SM – the leader in ***inventive*** GPS solutions.

Introduction
At its essence, a simple block diagram consisting of three entities describes LocatorNet^SM

The first entity is the device. A device is a mechanical and electronic unit that commuuicates with the LocatorNet^SM Processing Center.

The second entity is the LocatorNet^SM Processing Center. The LocatorNet^SM Processing Center is responsible for taking GPS information from the device, and producing a location that describes the current position of that device. The LocatorNet^SM Processing Center is then responsible for transmitting that location to a third-party service provider.

The third entity is the third-party service provider. The third-party service provider is responsible for delivering a service to the location of the device.

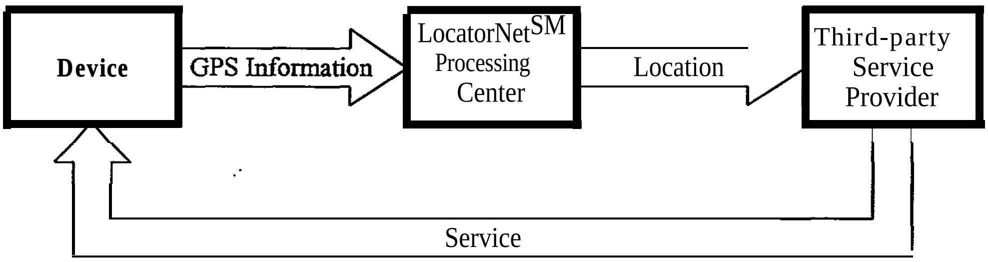


Figure I: Simple flow diagram for LocatorNet^SM

An example follows:

A distressing number of fatal accidents occur each year where the driver could have been saved if only the emergency medical services had been notified in time. Statistics show that driver survival rates are extremely poor even when injuries are relatively minor, unless medical assistance is received within an hour of the accident. In order to improve highway safety, an automatic emergency location or "Mayday" service, similar to that used for aircraft, is urgently needed to locate injured or stranded motorists.

In a typical scenario, Joe Smith is hurrying home to his family afraid that he may miss his son's birthday patty. While taking a comer too fast on a quiet country road near his home, his car skids on the wet road, spins out of control, and crashes into a ditch. The aribag deploys, but Joe is unconscious and bleeding from multiple fractures. Twenty minutes later, a passing motorist finds Joe but doesnt dare to move him because of his injuries. By the time he has located a telephone and called for help, Joe is already in critical need of emergency care due to shock and loss of blood.

A Mayday system using LocatorNet^SM technology would totally change this scenario. In our hypothetical case, Joe's wife had bought him a cellular phone with a TIDGET7 unit (a LocatorNet^SM device) as a Christmas gift the previous year. When the accident occurred, the device was activated by a built-in crash sensor and immediately sent an emergency call requesting assistance. The LocatorNet^SM Processing Center received the initial call which included GPS information from the device, and then calculated the crashed vehicle's location. This location was then sent to the State Police (third-party service provider) where various pieces of information were noted, including the user ID, the vehicle location, and the fact that the unit had been activated by the crash sensor. The State Police dispatch operator was connected to the cellular phone in the vehicle, but couldnt get any response from Joe. Immediately, an ambulance (the service) was dispatched with specific instructions: "Accident occurred on Shady lane Drive-Driver incapacitated-Medical history for Smith family will follow."

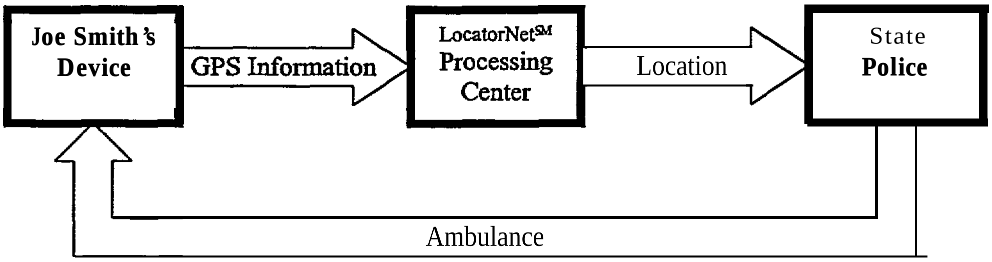


Figure 2: A sample LocatorNet SM implementation

The above example illustrates that a "Mayday" application is ideally suited for LocatorNet SM However, there are a number of very important features of the system that cannot be shown using such a simple example.

Customization

NAVSYS Corporation believes that its strength in engineering can best be utilized by providing custom services to its customers. To this end, LocatorNet SM has been designed to be scalable and customizable. The bottom line is that uses for LocatorNet SM are limited only by the imagination.

For example:

A LocatorNet SM device could be based upon:

- A vehicle-based cell-phone, with "on-demand" button activation
- A vehicle-based cell-phone, with crash-sensor activation
- A portable "shirt-pocket" cell phone, "on-demand" button activation
- A cargo-container-based unit using a pager-based communications link, with a time-delayed activation
- A hidden (surveillance) vehicle-based unit using a PCS communications link, with "on-request" activation

The location sent by the LocatorNet SM Processing Center to the third-party service provider might contain:

- User information (name, social security number, etc.)
- Medical information
- Vehicle information
- Information from a sensor (crash, temperature, etc.)

The third-party service provider might be:

- A public emergency organization ("911")
- Police, fire, or rescue

- **Roadside assistance**
- **Traveler direction service**
- **A corporate vehicle tracking entity**
- **A stolen vehicle recovery service**
- **A cellular telephone carrier**

LocatorNet^{SM} Devices

There are two ways in which a device may calculate a location from GPS information. The first way is by having all relevant processing and algorithms on-board the device, and performing the location calculation on the device itself. Such a device is termed a GPS Receiver. A GPS Receiver has a number of drawbacks, including:

- Power – Due to the fact that the GPS Receiver must run GPS algorithms locally on an advanced microprocessor, or digital signal processing (DSP) chip, GPS receivers user a lot of power, and battery life is a prime concern.
- Complexity – Also due to the act that the GPS Receiver run complex algorithms on-board, these device require extensive memory and supporting chips and circuitry. All of this increases the cost of a GPS Receiver.
- Time To First Fix (TTFF) – This term is defined as the time it takes a device from power-on until the time at which the first GPS satellite has been identified in the GPS data stream (e.g. the time at which the first satellite has been "tracked"). In a GPS Receiver, when the power is turned on, the only information the unit has is perhaps old almanac information from the last time that the unit was used Almanac information is not very accurate, and the GPS Receiver will have to then use this inaccurate information to guess at the current location of the satellites. In the likely case that the GPS receiver guesses wrong,. much time will be spent searching for a satellite that may not be visible. Typically, a GPS Receiver will take one or two or more minutes as the Time To First Fix
- Inflexibility – The algorithms to calculate location based upon GPS data are "hard-coded" into the GPS Receiver. Therefore, there is no easy way to upgrade its capabilities if advanced algorithms become available.
- Irrelevant Information – The output of a GPS Receiver is a latitude and longitude. Unless the user has a topographical map, and performs a timely 'location lookup", the information is without context, and therefore useless.
- Data Misusage – When using the information from a GPS Receiver, locations are presented in latitude and longitude. There are two very important features of GPS that are worth stating. First, GPS is statistical. Second, errors do occur. The first statement means that any location reported is subject to errors, and is of questionable value without qualification data. Fox example, the statement, "I will pay you 1 million" is worth much more if the units are dollars, than if the units are rubles. Unfortunately, with a GPS Receiver, there are no units.

As is apparent by these facts, there are a number of very serious issues that the GPS Receiver community has ignored. With these issues in mind, the founder of NAVSYS Corporation, Dr. Alison Brown (Ph.D. M.L.T./U.C.L.A), has invented a device that solves these and other issues – the TIDGET**7** The TIDGET**7** is a GPS Sensor. A GPS Sensor, as opposed to a GPS Receiver, does no on-board location processing. A GPS Sensor is simply a conduit to pass the GPS data along a communications channel.

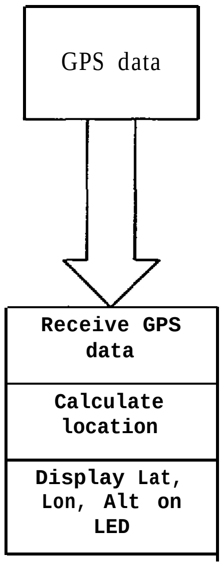


Figure 3: GPS Receiver

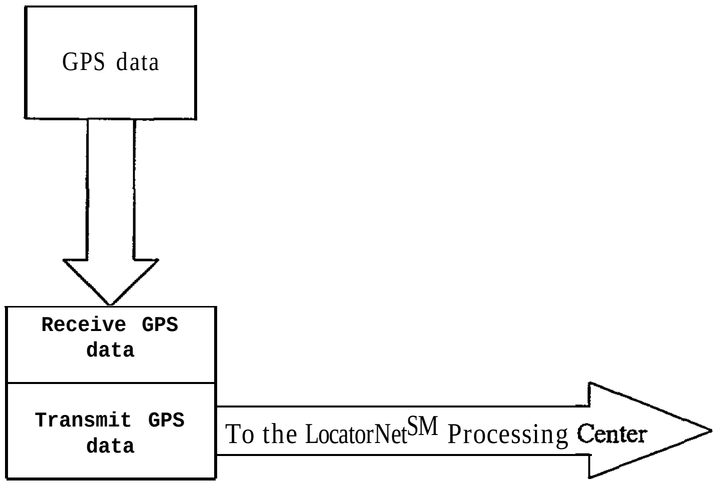


Figure 4: GPS Sensor

A GPS Sensor has a number of benefits, including:

- Power - A GPS Sensor is essentially a pass-though device.It is very simple and requires very low power. The benefit to low power consumption is that a GPS Sensor is able to integrate another device with the GPS Sensor, such as a cell phone, to create a very useful and versatile device. A GPS Receiver uses too much power to make this. integration possible.
- Simplicity - A GPS Sensor has no need for extravagant on-board processing.This means that the device is more reliable, and less expensive.
- Time To First Fix (TTFF) - Using the techniques described later in the section on the LocatorNet℠ Processing Center, once the data is received, the Time To First Fix (on a well-tuned system) is on the order of 5 seconds. Compare this to one or two or more minutes for a GPS Receiver.
- Flexibility - The algorithms to calculate location based upon GPS data are not "hard-coded" into the GPS Sensor. They reside on powerful computers at the LocatorNet℠ Processing Center. Therefore, any one change made at the LocatorNet℠ Processing Center will benefit each and every device in the field.
- Relevant Information - Due to the fact that the GPS Sensor's advanced design is very low power, and due to the fact that the communications link for the GPS data can be selected so that it is the same as a human-accessible voice link (e.g. a cellular telephone link), an irrelevant position does not need to be shown. The position can be displayed to a dispatch operator who can display that position on an electronic map, and therefore can put the location into context before dispatching a service.
- Archival - Every piece of information relating to an incident is stored in the LocatorNet℠ Processing Center database.
- Reproducibulity - Every incident run through the LocatorNet℠ Processing Center can be reproduced because the data has been saved.
- Data Integrity - Using a location without qualification is dangerous as specified above. All locations specified via the LocatorNet℠ Processing Center are qualified, this means that the ancillary information, such as: Area of Confidence and any Errors are reported

Therefore, with any location received from the LocatorNet[SM] Processing Center, data misuse rarely occurs because the location is placed in statistical context.

Consider the following two statements from a dialog between two friends:

"I will meet you at 39.048723, -104397746 at 5:00 PM"

"I will meet you at Joe's Restaurant, at the comer of Academy Boulevard and Dublin Road at 5:00 PM"

The difference between the two statements is that (unless you carry topographical maps at all times) the first statement contains no relevant context to "place" the lacation. The second statement has converted the location to a relevant context. This example is exactly analogous to the end-product of a GPS Receiver compared to a GPS Sensor using the LocatorNet[SM] Processing Center.

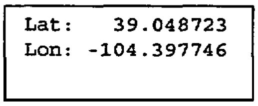


Figure 5: The end result of a GPS Receiver

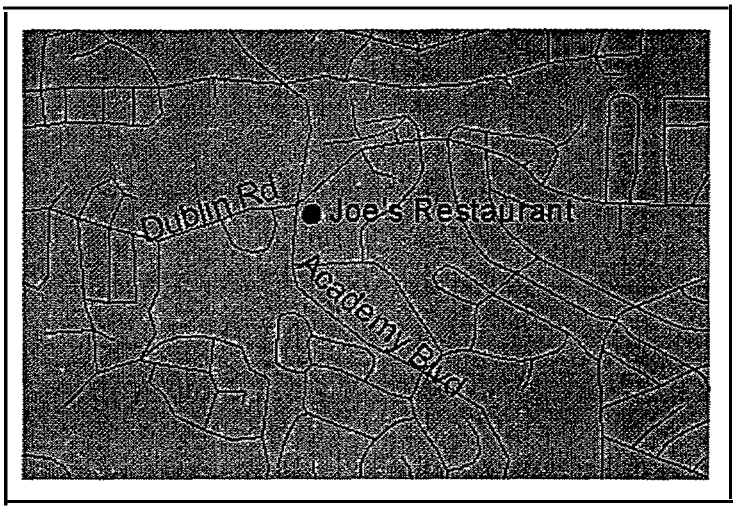


Figure 6: The end result of a GPS Sensor using the LocatorNet[SM] Processing Center

Current devices under development by NAVSYS include:

The GPS Phone – A personal hand-helddevice featuring both cell phone operations, and GPS location services. At the device, GPS data is captured by the NAVSYS TIDGET7 This device is able to communicate location via either data of AMPS, or CDPD.

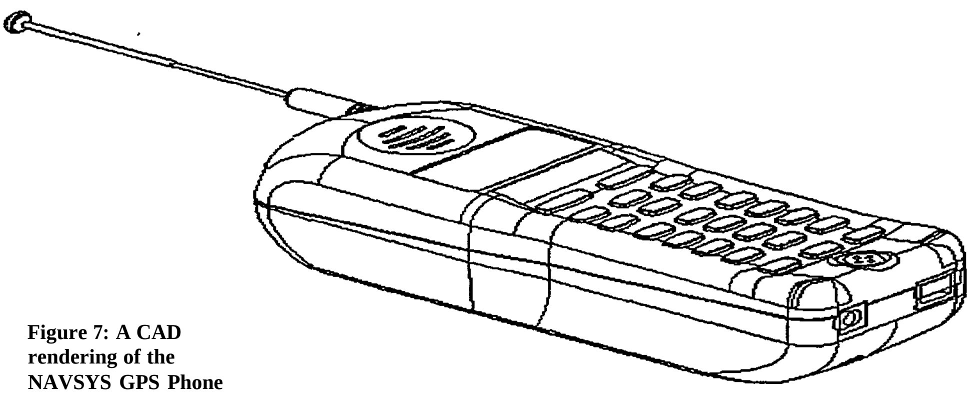


Figure 7: A CAD rendering of the NAVSYS GPS Phone

The In-Vehicle Unit (IVU) – A vehicle-based cell phone integrated with GPS location services. This device communicates location via data over AMPS.

Other – NAVSYS is working with various customers on specialized devices, including a device that features location only, using GDPD as a communications medium

Each LocatorNet(SM) device is capable of functioning in a number of different modes:

- **Standard Mode is** the default, "on-demand" mode activated by a user request at the device.
- **Tracker Mode is a mode whereby location requests are made** on a timed interval, whether that is every 2 minutes, or every 1 hour. In this manner, a device may be "tracked", e.g. its position is updated enough so that the route or trend can be discovered
- **Finder Mode** occurs as a request from the LocatorNet(SM) Processing Center to the device. The user of the device need not be involved. This mode essentially answers the question "where are you?"

LocatorNet(SM) Processing Center

The LocatorNet(SM) Processing Center is a network of modules designed to accept GPS information from a device, and with that GPS information, calculate a location. The location of the device (along with any other user information) is then passed on to a third-party service provider.

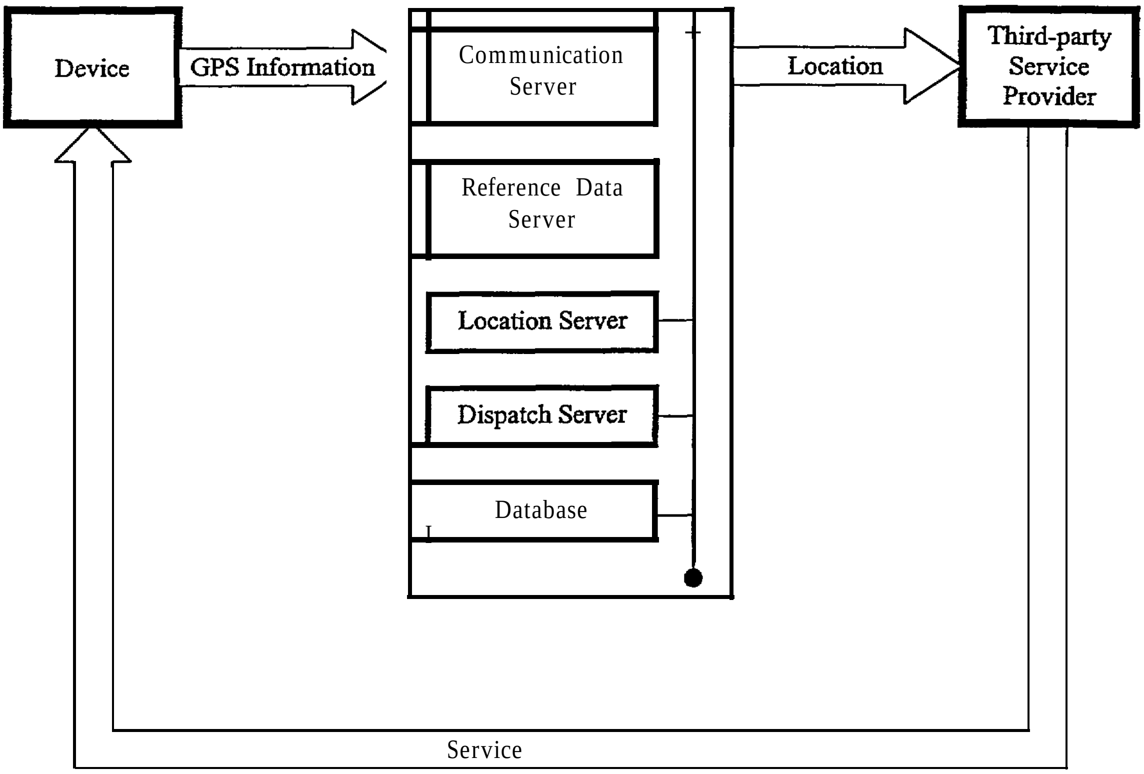


Figure 8: Detailed diagram for LocatorNetSM

One of the reasons why the LocatorNetSM Processing Center is so powerful is that it is designed around the following principles:

- Each module is responsible for a specific task, and optimized towards that end
- All unnecessary processing and intra-process communication is off-loaded onto the database, so that the modules can do what they were designed to do.
- The capacity of the system is configurable because of module scalability.

Communication Servers

The responsibilities of the Communication Servers are:

- Act as a gateway between a device and the LocatorNetSM Processing Center
- Accept identification and GPS information from the device
- Place all device information into the database

A Communication Server will physically interface with the communication protocol that a particular device is implementing. For example, the Communication Server that accepts data from an AMPS cellular phone connection is called the "CommServer" Alternately, the Communications Server that accepts TCP/IP data from a CDPD connection is called the "IP Server"

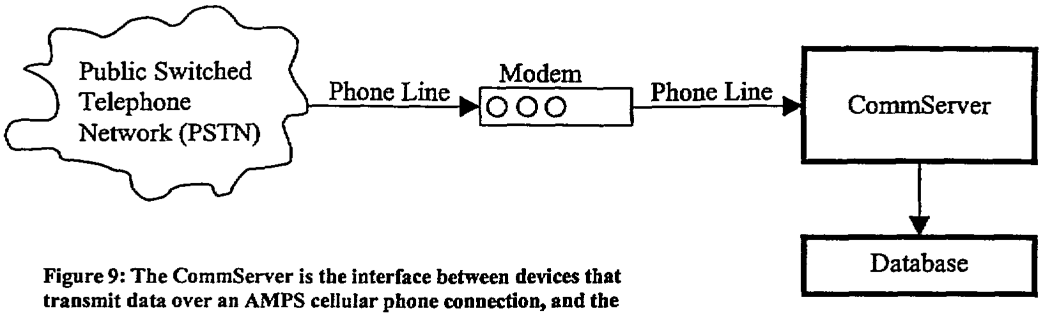


Figure 9: The CommServer is the interface between devices that transmit data over an AMPS cellular phone connection, and the LocatorNet℠ database.

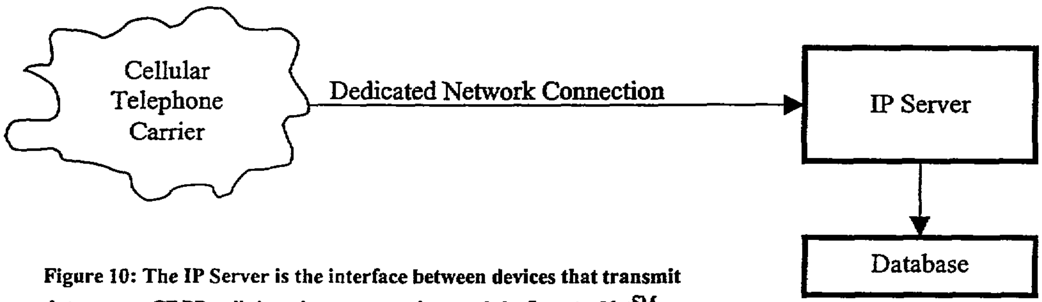


Figure 10: The IP Server is the interface between devices that transmit data over a CDPD cellular phone connection, and the LocatorNet℠ database.

A device will establish a connection with a particular Communications Server, and then information is exchanged.

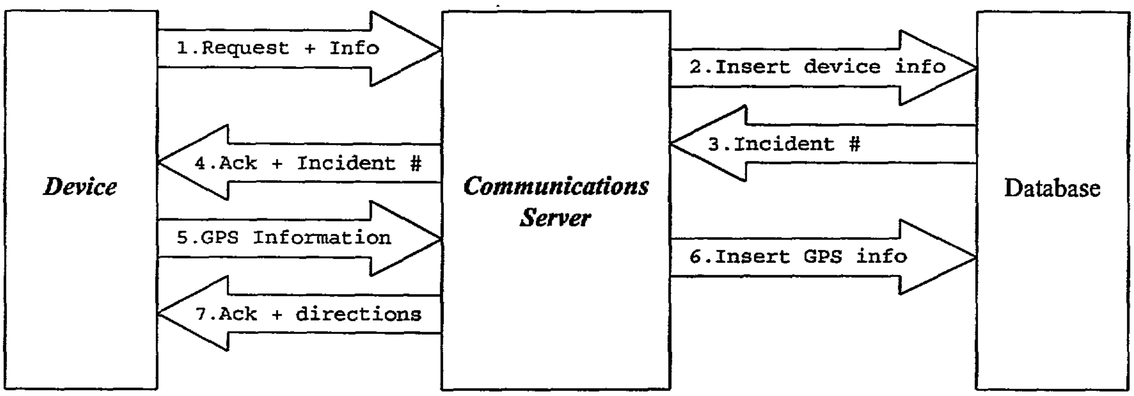


Figure II: Block diagram of information exchange between device and Communication Server

1. **Request + Info** – The device will initiate communications. This request will include user information, such as a user id, a device identification number, and the type of service requested.
2. **Insert device info** – The Communication Server will then pass the information previously received to the database. The database will assign a unique incident identifier to this incident, and insert all device information into the database.
3. **Incident #** - The database will then pass the unique incident identification number back to the Communication Server.
4. **Ack + Incident #** - The Communication Server then informs the device that the request has been acknowledged, and to further reference the incident by the enclosed identification number.
5. **GPS Information** – The device then sends GPS information to the Communication Server.

6. Insert GPS Info – The Communication Server then inserts this (time tagged) GPS information into the database.
7. Ack + directions – The Communication Server then sends an acknowledgement to the device, specifying that the data has been inserted Also, any further directions (if any) are sent to the device.

Ensuring that the GPS information is correctly time tagged is dependent ***on the device type. Certain*** devices rely on the Communication Server to maintain correct GPS time (e.g. the IVU), and certain devices use techniques such as Network Time Protocol (NTP) ***to*** communicate with dedicated hardware in order to ***ascertain correct*** GPS time. The net result is that by the time the GPS information is in the database, there is an accompanying time tag field that describes the true GPS time at which the data was taken

Reference Data Server

The Reference Data Server is responsible for keeping precise and up to date information in two areas: ephemeris and differential corrections. Connected to the Reference Data Server (or "RDS") is dedicated GPS hardware. This hardware is hooked up to an antenna that has been placed in a surveyed location.

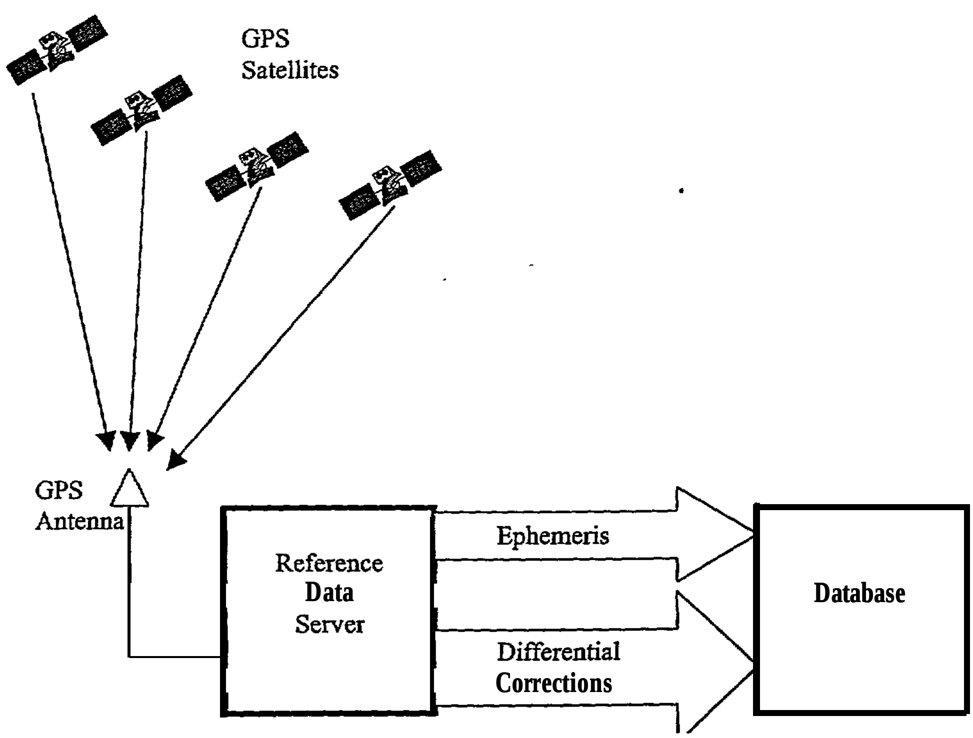


Figure 12 Block diagram of Reference Data Server Operations

Ephemeris data essentially answers the following questions:

- What satellites are visible at my location?
- Where are they in the sky?

Ephemeris data is valid over a very wide area. For example, the continental 48 U.S. states "see" basically the same satellites.

Due to purposeful degradation of the GPS signal by the U.S. Government to implement a concept known as Selective Availability ("SA"), techniques have been developed to increase GPS accuracy. One of these techniques is known as applying differential corrections. Given that the location of the RDS antenna is known, the RDS can, for any set of satellite measurements, calculate its own position. The RDS then takes the difference between its calculated position, and its known position, and effectively computes a "reverse" GPS solution. This reverse solution enables the RDS to compute a (differential) correction for each of the satellite measurements {each measured distance to a satellite is known as a pseudo-range). (This technique has been patented by NAVSYS.) This time tagged pseudo-range correction ("PRC") is then stored in the database for later use.

The rate at which differential corrections need to be calculated is configurable. NAVSYS has found that updates at approximately every 3 seconds are near optimal Differential corrections are valid for no more than a radius of 100-200 miles. A LocatorNet[SM] base station supporting a wide area can address the differential correction situation in a number of different ways, including:

- Installing multiple Reference Data Stations connected by a remote link to the LocatorNet[SM] Processing Center
- Implement a subscription satellite-based differential correction service

Location Server

The location server implements advanced GPS algorithms to perform two main tasks. The first task is tracking,. Tracking is the process of taking raw GPS information from the device and identifying each of the visible satellites in the data. The second task is navigation. Navigation is the process of calculating a position (latitude, longitude, and altitude) from GPS information.

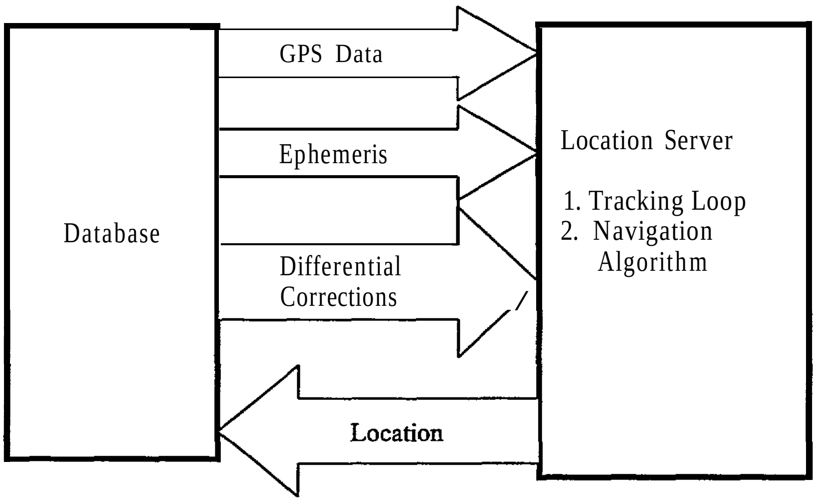


Figure 13: Block diagram of Location Server operations

The Location Server receives the raw GPS information from the database for a particular incident. Because that data is time tagged, the Location Server can also request the time-matching ephemeris and differential corrections. Based upon the satellites reported in the ephemeris, the Location Server can only Yook" for those satellites, which greatly reduces the amount of time the Location Server has to spend on tracking. The actual time that it takes the Location Server to perform tracking is based upon the amount that the crystal oscillator on the GPS portion of the remote device has drifted. Based upon prevailing temperature and age, an oscillator will drift from its specified frequency by some amount.The ability to quickly determine the amount of this drift is paramount in a system being defined as "well-tuned". With a well-tuned system, however, the amount of time spent tracking all satellites should be less than 5 seconds. This time may be reduced by configuring the Location Server in Rapid Acquisition Mode, a mode using Fast Fourier Transform techniques to track the data.

Once all of the satellites are tracked, the Location Server computes its internal satellite measurements for this set of GPS information into a position. The process is called navigation, and is very fast {on the order of less than 1 second).

The accuracy of the Location Server is dependent on many things. It cannot be stated that the accuracy of the system is some value of meters per incident, because there are direct scaling factors that must be applied. The following factors affect accuracy:

- The amount of data taken
- The Signal to Noise Ratio (SNR) for each satellite tracked
- The Dilution of Precision (DOP) values for the given satellite constellation
- Others, such as timing errors

The NAVSYS TIDGET7 samples the Ll GPS spectrum at a rate of 2 Mbps. Therefore, each .001 second of GPS data corresponds to 250 bytes (2000 bits) of raw GPS data. Given no out of the ordinary circumstances, the accuracy of the system is nominally defined as follows:

- 20 ms of GPS data (5,000 bytes) corresponds to 50m accuracy (1 sigma)
- 62-100 ms of GPS data (15,500 bytes to 25,000 bytes) corresponds to 10m accuracy (1 sigma)

The minimum number of satellites necessary to calculate location by the Location Server is typically four. However, certain techniques allow fewer satellites to be used. Altitude aiding, via a Digital Elevation Map (1:24,000 allows a location to be calculated with only three visible satellites. Using advanced techniques and utilizing the power of the LocatorNetSM Processing Center. NAVSYS has developed a technique whereby if only two satellites are visible, a location is possible! This technique calculates a likely "area" where the device is location, specified by a "line" of a certain thickness. Using a correlating technique which matches to a feature (such as a road), the likely position of the device can be determined. This is only possible with the LocatorNet^SM Processing Center and NAVSYS' unique GPS Sensor approach to GPS.

Dispatch Server

Once the LocatorNet^SM Processing Center (LPC) has calculated a location from a set of GPS information, this location, and other information, is passed to a third-party service provider (3PSP). There are a wide variety of options available for this functionality.

Non-real-time, Reports Only

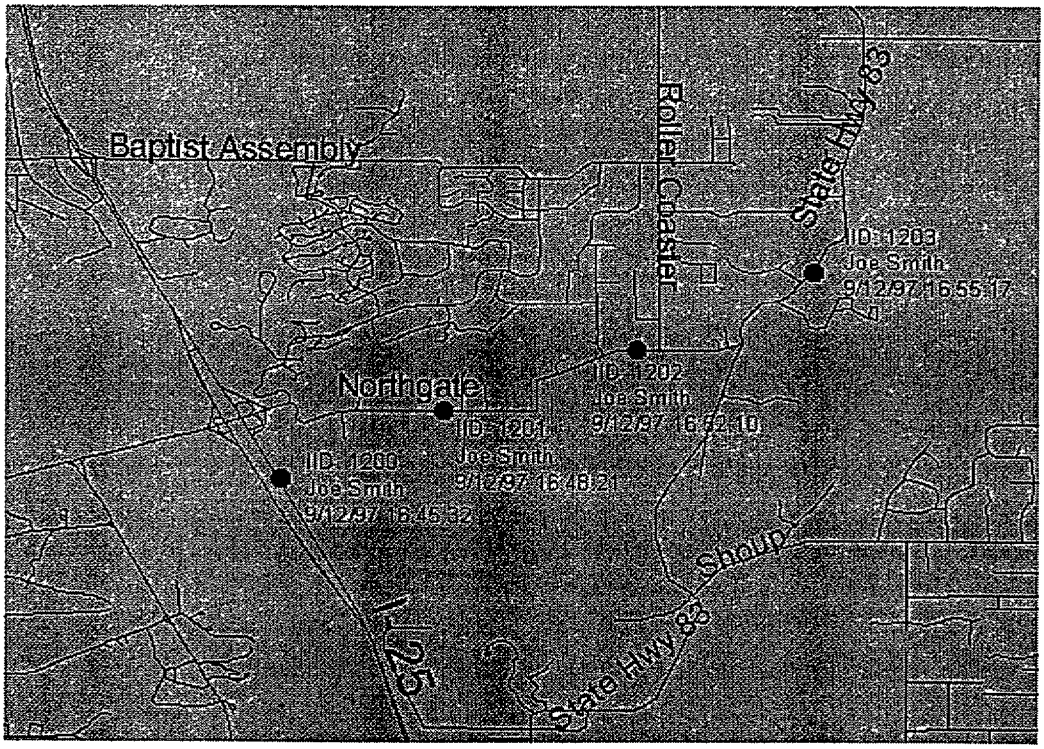
Suppose the 3PSP has no need for dispatching services or mapping, and is **only** interested in knowing the locations of the incidents from the previous day. In this case, the LPC can be configured to produce reports of the incidents, and these reports can be sent to the 3PSP via email, fax, overnight, etc. These reports can be customized **to** include any necessary information.

Date	Time	IID	User	Lat	LOrl	Alt	Notes
9/12/97	16:45:32	1200	Joe Smith	39.128559	-104.656580	2050.5	
9/12/97	16:48:21	1201	Joe Smith	39.345678	-104.845943	2047.3	3 SVs visible
9/12/97	16:52:10	1202	Joe Smith	39.678901	-104.098445	2052.3	
9/12/97	16:55:17	1203	Joe Smith	39.893755	-104.847264	2051.0	

Figure 14: An example of Non-real-time, Reports Only

Non-real-time, Reports and Maps

This option is essentially the same as the Non-real-time, Reports Only option, however, included with the report is a printout of the locations on a map.



Date	Time	IID	User	Lat	Lon	Alt	Notes
9/12/97	16:45:32	1200	Joe Smith	39.128559	-104.656580	2050.5	
9/12/97	16:48:21	1201	Joe Smith	39.345678	-104.845943	2047.3	3 SVs visible
9/12/97	16:52:10	1202	Joe Smith	39.678901	-104.098445	2052.3	
9/12/97	16:55:17	1203	Joe Smith	39.893755	-104.847264	2051.0	

Figure 15: An example of Non-real-time, Reports and Maps

Real-time, Reports Only

Suppose the 3PSP has no need for dispatching services or mapping, b ut wants the location reports in real time. In this case, NAVSYS would install the Dispatch Console at the 3PSP, and connect to it via a dial-up line, direct line, intemet connection, or other option. The report information would then display real-time.

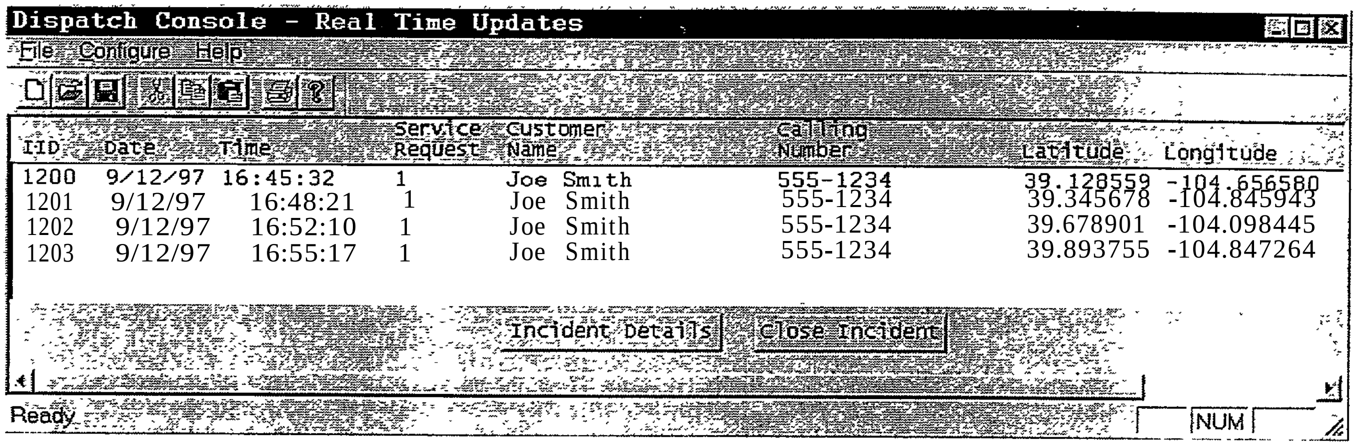


Figure 16: An example of Real-time, Reports Only

Real-time, Basic Mapping

In this scenario, the 3PSP wants to know about incidents in real tie, but has no in-house mapping or dispatch capabilities. NAVSYS would install both the Dispatch Console, and the Dispatch Mapping modules at the 3PSP and connect via a dial-up line, direct line, intemet connection, or other option. The location information would then display real-time on a Geographic Information System (GIS).

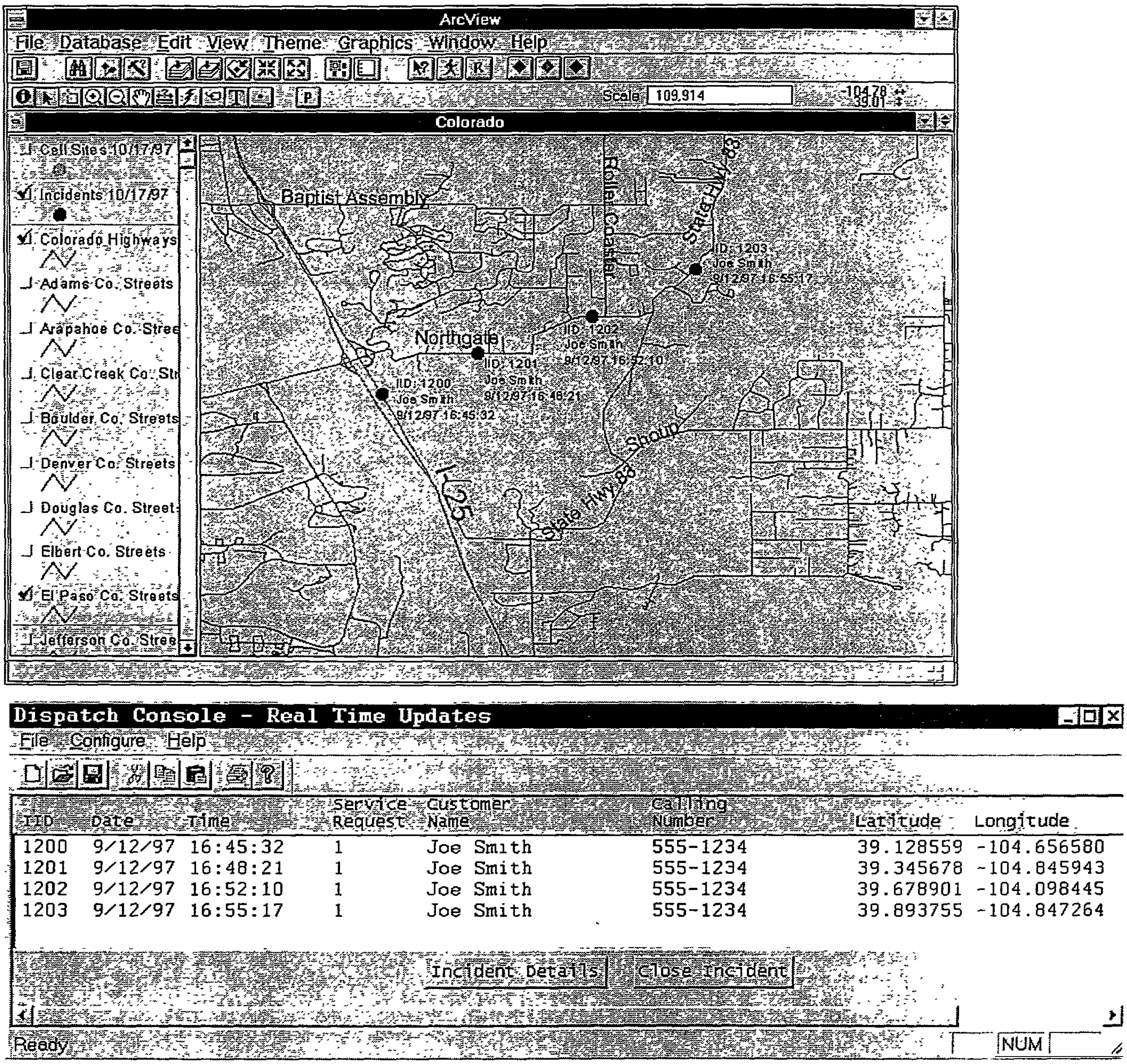


Figure 17: An example of Real-time, Basic Mapping

Real-time, Custom Mapping

A 3PSP might have in-house GIS, mapping and dispatch operations already in place. In this scenario, the 3PSP would define the communication protocol for NAVSYS to deliver location information to their own network or database. In tbis manner, NAVSYS would configure its Dispatching Server to accommodate the 3PSP's in-place system. The manner of delivery again could be via a dial-up line, direct line, internet connection, or other option

Any other option that a 3PSP could request could by supported by NAVSYS as well.

Database

At the heart of the LocatorNet[SM] Processing Center is an Oracle 7.3 Relational Database System (RDBS). In this database is stored information about each user of the system, for example:

- ***Name***
- Address
- Medical history
- Vehicle type
- Social Security Number
- Phone Number
- Person to Contact, with Contact Phone Number
- other

Additionally, each and every piece of GPS information is stored in the database, including: ,

- GPS device data
- Ephemeris
- Differential Corrections

This means that any incident can be re-created and verified All data is then downloaded to tape for a customer-specified archive period.

Summary

LocatorNet[SM] is the vehicle by which NAVSYS Corporation is able to provide location services. Through years of thoughtful design and engineering, NAVSYS has been able to create a module, scalable and customizable system carefully designed to be integrated with third-party service providers. It is because of this and similar endeavors that NAVSYS is known as the leader in inventive GPS solutions.

LocatorNet℠ Specifications

TIDGET® Low power, passive sensor, instant-on
Sample rate: 2 Mbps, 1 bit A/D
Antenna frequency: L1
Typical data collection: 10 to 100ms @ 250 bytes/ms
Nominal pseudo-range rating 10m @ 62ms

LocatorNet℠ Devices Standard mode operations; on-demand (data push)
Finder mode operations; where are you? (data pull)
Tracker mode operations ("continuous" data at regular intervals)

IP Server Device communication protocol:TCP/IP
Cellular protocol: CDPD
Detects and repairs missing packets

Commserver Device communication protocol: modem connection
cellular protocol: AMPS

Reference Data Server Monitors GPS constellation precise ephemeris
Calculates differential corrections via patented algorithm
Differential correction rate is adjustable (default = 3 second updates)

Location Server Can navigate with 2 visible satellites
TIFF < 10 seconds (offset-tuned device data, nominal)
Track and navigate < 15 seconds (offset-tuned device data, nominal)
Tracks only satellites reported visible by Reference Data Server
Navigation module reports user-configurable information:

- ***Space Vehicle Number (SV)***
- ***Signal to Noise Ratios (SNR) fro each SV***
- ***Dilution of Precision (DOP) values***
- ***Navigation solution: Lat/Lon/Alt***
- ***Area Of Confidence(AOC) (1 sigma)***
- ***Any other measurement (tau, tracked offset, psedo-range corection, etc.)***

Navigation module reports error/out-of-bound conditions:

- ***Dilution of Precision (DOPs) too high***
- ***Not enough satellites to track***
- ***receiver Autonomous Integrity Monitor (RAIm) error***
- ***Other errors (e.g tracking algorithm did not converge, diff corr too large)***

Nominal accuracy (62ms of data): 10m (1 sigma, differentially corrected)
Nominal accuracy (20ms of data): 50m (1 sigma, differentially corrected)

Database Oracle 7.3
Customizable device and subscriber information maintained
Ephemeris and differential corrections are archived
Each set of GPS data is archived
Each navigation solution and ancillary information and errors are archived
Cellular tower and face information maintained for each cellular carrier

Dispatch Workstation Can connect to Processing Center via various methods:
Network, Internet, dial-up, dedicated line, etc.
GIS system is ArcView, Maps are TIGER format
Cell sites are plotted for each incident as a coarse fix
Area of Confidence circles are plotted for each location
Dispatch operator retains complete control, e.g. pan, zoom, delete, etc.