

UC Berkeley

Research Reports

Title

Studies Of The Adoption And Use Of Location And Communication Technologies By The Trucking Industry

Permalink

<https://escholarship.org/uc/item/7f78r3w1>

Authors

Scapinakis, Dimitris A.
Garrison, William Louis

Publication Date

1991

Program on Advanced Technology for the Highway
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA AT BERKELEY

Studies of the Adoption and Use of Location and Communication Technologies by the Trucking Industry

Dimitris A. Scapinakis
William L. Garrison

Research Report UCB-ITS-PRR-91-2

This work was performed as part of the Program on Advanced Technology for the Highway (PATH) of the University of California, in cooperation with the State of California, Business and Transportation Agency, Department of Transportation, and the United States Department of Transportation, Federal Highway Administration.

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

This paper has been mechanically scanned. Some errors may have been inadvertently introduced.

STUDIES OF THE ADOPTION AND USE OF LOCATION AND COMMUNICATION TECHNOLOGIES BY THE TRUCKING INDUSTRY

Dimitris A. Scapinakis and William L. Garrison

ABSTRACT

This discussion paper describes the eight tasks to be undertaken in a just-initiated investigation of the adoption and use of positioning and communication technologies by the trucking industry. Prior to presenting the tasks, an update is provided of previously gathered information on the positioning and communication systems available to the trucking industry. This paper will be distributed to interested parties, and comments on our approach are requested.

1. INTRODUCTION

The increasing use of in-cab communications and location reporting (positioning) equipment has the potential to change the way the trucking business is conducted by affecting route scheduling, the organization of trucking tasks, and relations with shippers and receivers of goods. (Figure 1 shows an example system.) Increasing use may also provide opportunities for efficiencies to be gained by the implementation of traffic control systems by transportation agencies. Of special interest to the authors are lessons to be learned from the trucking industry's technology adoption decisions: for instance, what motivates equipment and service suppliers; how have uses of systems changed? The answers to such questions may illuminate development strategies for achieving broadly applicable traffic management systems, and, more broadly, productivity enhancing strategies for transportation systems.

System adoption is underway. Trade magazines of the satellite communications (e.g., ***Satellite Communications***) and trucking industries (e.g., ***Heavy Duty Trucking***) regularly refer to companies that have purchased or are testing units that will allow drivers to communicate with headquarters and permit dispatchers to send messages to drivers. Operations efficiencies and service improvements motivate the adoption of the technology. The following is a list of benefits as perceived by fleet managers and reported in published interviews or articles in the trade press:

1. Improved Service to time-sensitive customers.
2. Customers see benefits and are strongly pushing towards the installation of systems.
3. A carrier gains competitive advantage by offering advanced communications services to its customers. A small firm can continue expanding without abandoning the personal touch in the services they offer.
4. Increased safety.
5. Drivers waste less time waiting at pay phones, sleep more, and earn more money. Many drivers consider the electronic terminal in the cab something of a status symbol. Their satisfaction leads to better relations and reduced turnover.
6. Long distance phone calls are eliminated, resulting in reduced phone bills.
7. Scheduling flexibility increases the number of trips per vehicle.
8. Real time information about loads reduces the number of empty miles.
9. Improved driver accountability since drivers know they are not “alone” any more.
10. Vehicle maintenance costs are minimized if vehicle attributes bearing on maintenance are monitored.

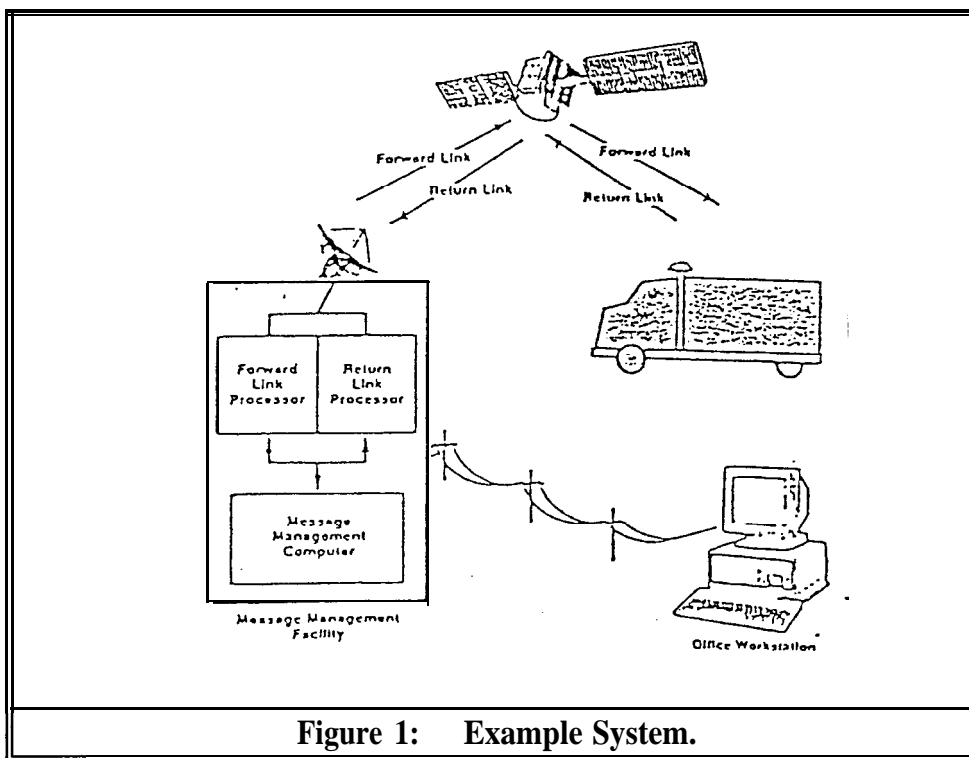


Figure 1: Example System.

The literature especially stresses item 6 above, phone calls. In general, “wireless” messages are less expensive than phoned messages, but reductions in other message related costs are more important. There is reference to the miles that must be driven for the driver to find a suitable truckstop for phoning, the time lost while waiting for an available phone, and the ability to be contacted by the dispatcher. Without mobile communications, messages from the dispatcher to the driver must wait until the driver phones.

In addition to these factors, the literature refers from time to time to “crises managed.” For instance, a truck with a priority shipment breaks down in a remote area of Nevada. The driver communicates the problem, and a way to manage it is implemented. In addition, there is reference to the use of systems when hazardous materials are transported.

The information provided above is from a preliminary survey of positioning and communications technologies, as well as a review of their implications for highway traffic operations completed by the authors in June 1990. The information presented in that report was mainly from industry sources, such as advertising materials and news stories in trade journals.

Having introduced the technology adoption aspect of our topic, the discussion to follow will focus on the technologies available or becoming available.

The discussion begins by stating the distinction between radiodetermination and mobile communications systems. Then, background information is presented on radiodetermination systems, followed by a closer look at three systems. Mobile communication services, both terrestrial and satellite based are reviewed next, followed by some new system concepts.

Again, the information to be presented is from a preliminary literature survey. One of the tasks to be identified toward the end of this paper is the improvement of the information available.

2. SERVICES

Equipment vendors, or value-adding third parties, offer two services to fleets:

1. The position of the vehicle is reported to fleet headquarters.
2. Information is exchanged between vehicles and headquarters. The information may be driver-dispatcher operations messages, but may also convey tractor or trailer operating parameters (e.g., reefer temperatures), trailer hitching or unhitching, and so on.

These services are often associated with two terms in the literature: *radiodetermination* and *mobile communications*. There is communication in each case. The distinction alludes to differences in frequencies, technical requirements, and functions. The first systems were used by aircraft and ships and this is reflected in the definitions.

¹ **Garrison, W. L., and Dimitris A. Scapinakis**, Adoption of Advanced Positioning and Communication Technologies by the Trucking Industry, ITS-RR-90-9, June 1990.

Radiodetermination is the determination of the position, velocity or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of radio waves. A radio determination system can be either terrestrial (e.g., LORAN-C) or satellite based (e.g., TRANSIT, GPS). When the latter is the case, the term radiodetermination satellite service or RDSS is used.

Radionavigation is radiodetermination for the purposes of navigation. Navigation seeks the safe movement of a vehicle from one point to another. Navigation systems are designated “safety-of-life” systems and should be continuously available within their intended area of coverage. To avoid any interference, exclusive frequency bands are allocated to such systems (they are under a so called “protected status”). Navigation is normally performed in the vehicle itself without this precluding reporting of its position elsewhere.

Radiolocation (sometimes also referred to as radiopositioning) is radiodetermination used for purposes other than those of radionavigation. The vehicle may not need to obtain its position from the radio aid. It might be, say, a truck moving along a road known to the driver. Rather, the position is calculated to serve the needs of a central station, say, a trucking dispatcher. A system offering radiolocation does not need to be continuously available. Radiolocation systems are not thought of as “safety-of-life” systems nor are they given “protected status” for frequency allocation purposes. They may share their frequencies with other systems, and this may cause interference problems. A radiolocation system may be simpler to set up than a radionavigation system although this depends on the particular application.

Mobile communications refers to communications with a moving terminal. The mobile terminal may be on land or sea or in the air. Mobile to stationary terminal communication may be either via a terrestrial relay network (e.g., cellular phones) or a satellite network, in which case the term mobile satellite service or MSS is used. The data carried may be voice, text, location information, and so on. The intended application influences the desirable size, shape, and power requirements of terminals and antennas. For instance, a bulkier and more expensive terminal can be installed in a tank ship that costs million of dollars, while a compact, light, low-power unit would be more suitable for a truck cab.

The brief mention of examples of services may be useful. Suppose a truck is on a highway between places A and B. The dispatcher may wish to tell the driver to make an additional stop at place B. The request may be sent by voice or appear as a message on the driver’s terminal. The dispatcher may wish to know the location of the truck. An inquiry to the driver might get the answer, “halfway there.” As an alternative, location information could be sent from the truck without involving the driver. Radiolocation provides latitude and longitude (x,y) information and altitude, if desired. Trucks operate on routes and among places with street addresses, and software to convert x-y coordinates to streets and

addresses may be needed in some applications.

3. RADIODETERMINATION SYSTEMS

Modern navigation techniques emerged with the growth of the sea trades and were later applied to aircraft movements. Land navigation has emerged as a technique for application in schemes for intelligent vehicle highway systems (IVHS). New applications are sought for existing navigation systems not specifically designed for use over land. Several systems are operational or have been proposed: hyperbolic systems (e.g., OMEGA, DECCA, LORAN-C) using radio beacons; satellite systems (e.g., GPS); multiple beacon systems using a large number of closed spaced, low-power, beacons; dead reckoning systems; hybrid systems (e.g., roadside beacons with dead reckoning). Hyperbolic and satellite systems are used extensively. Since the former were not designed for use over land they do not cover many inland locations of interest. The latter may not provide a line of sight in urban areas because of tall buildings, bridges and other obstructive objects. In the following, satellite systems are considered in more detail.

Since the first artificial satellites were launched they have been used for position calculations. Range (i.e., distance) is information that can efficiently be extracted using satellite signals. Theoretically, three measurements of distance to known points are needed to unambiguously locate an object in space. In practice, one of these measurements can be eliminated by either rejecting geometrically improbable solutions or by knowing the user's altitude (as is the case in maritime applications). Distances are derived from the time it takes a signal to travel from satellite to user. This introduces one more variable to the location finding problem, time.

One satellite is unusable for navigation purposes because one needs at least two ranges, and the same satellite cannot be used twice without weakening the geometry. Using two satellites, position can be determined if the user, either has a clock aligned to that of the satellites' (assuming both satellites are on the same timebase) or the user's terminal retransmits the signal to an earth station that does have a clock. The first approach introduces enough sources of uncertainty to require a third satellite for calibration. In the second approach (and the one proposed in Geostar's RDSS system), the user's terminal must transmit, and this puts a limit on the maximum number of users. In any case, users must know their height (this should be the geocentric height not simply height above sea-level). Three satellites can give two ranges and hold a clock synchronized. The users still need to input their height to get a two dimensional fix. With four or more satellites one gets three distance measurements and one time measurement. Thus, a three dimensional position fix is obtained without any external references. In summary, a system based on two or three satellites can only provide low accuracies, in the order of few miles, depending on the kind of height information provided by the user.

However, these low accuracies may be acceptable for some land based applications (e.g., when locating a truck in a remote area, as opposed to locating a rail car at a classification yard).

A civil navigation system using dedicated satellites has yet to be launched although specific frequencies have been allocated to RDSS systems. Hesitation in launching such an endeavor is understandable when one considers the staggering costs of designing, manufacturing, insuring, launching and operating the necessary satellites. To achieve 90% world coverage from geosynchronous orbits (one of several orbits used by satellites) at least 10 satellites would be required. With an average satellite life of 7 to 10 years, system unit operations costs would be great and a large number of users must be assured. GPS receivers coming on the market at a constantly decreasing cost (now a GPS receiver costs about a few thousand dollars) further question the commercial viability of a civilian dedicated system. Geostar, however, has proposed such a system and currently is in the process of taking the necessary actions to implement its plans.

The only alternatives to a civil dedicated system are either the use of navigation systems designed for and operated by the military or the sharing of payloads with communications satellites. These solutions are not without problems. Military needs are not similar to civilian ones. Military designers have to take costly precautions against jamming, the satellites must continue operating even if ground contact is lost, and a broadcast system is necessary so that users will not disclose their positions. These considerations add to the complexity of a system such as the Global Positioning System (GPS). From an international perspective, an open question remains whether the user community is prepared to accept a system which is under the control of the military of a single country.

The second alternative is the use of transponders on-board existing communications satellites (operating at frequencies in the C-Band or K-Band). Problems here arise from the need to reconcile different engineering requirements for location and communication. Communications satellites do not need to keep track of the precise location of the space platform. When deriving locations using satellites however, the exact position of satellites has to be known. The geometrics of a geosynchronous orbit (popular with communications satellites) are such that the calculated location has a considerable uncertainty in latitude. Also, equatorial regions (about 50 from the equator) are in disadvantage. In addition, satellite operators adjust the orbit so the satellite can better "see" an earth station. These station keeping manoeuvres must be known otherwise accurate positions can not be calculated.

The economics of satellite building, launching, and operating make the use of navigation payloads onboard existing geostationary communication satellites a preferred alternative for civil systems. The synergy between communications and navigation has long

been recognized. Two decades ago, the International Maritime Organization (IMO) was preparing the organizational plans of an agency that would provide radiodetermination and communication services, among other things. The U.S. Government, experimenting with the ranging capabilities of communication satellites (ATS series of satellites) operating at L-Band frequencies concluded that potential for practical applications existed. Additionally, one of INMARSAT's stated purposes when founded was the provision of radiodetermination services. INMARSAT offers the international institutional framework to provide both mobile communications and radiodetermination services to all modes of transportation anywhere in the world. It is for this reason that INMARSAT's involvement is significant.

The Federal Communications Commission (FCC) when allocating frequencies made a distinction between RDSS and MSS on the grounds that they serve different customer needs. It ruled that RDSS is primarily intended to provide radiodetermination information with some ancillary message capability. MSS on the other hand, is primarily a system providing voice and rural radio. While technically correct, the distinction is somewhat artificial and the link between RDSS and MSS may grow stronger in the future.

Three RDSS system concepts will be outlined in the following sections: GPS, Qualcomm's QASPR and Geostar's RDSS proposal. The first two are operational. Other systems include those proposed by USSR (GLONASS) and the European Space Agency (ESA).

3.1. GPS:

The U.S. government seeking to improve services and to reduce unnecessary proliferation and overlap of federally operated radionavigation systems (among them OMEGA, TRANSIT, LORAN-C) proposed the Global Positioning System (GPS), also known as Navstar. This system will eventually comprise a constellation of 18 satellites plus back up satellites on circular orbits at about 20,000 km of altitude. The satellites are arranged so that four will always be visible from all points on the earth. The three system components (space, control and user equipment) will be fully operational by the mid 1990's. Users can determine their location and speed and the time using passive receivers with built-in microprocessors that perform calculations. The equipment is easily built and getting smaller and less expensive. One manufacturer is already offering a small-sized GPS module that can be integrated into other electronics equipment.

For national security reasons, civil accuracies have been restricted to about 100 meters, making use of the Standard Positioning Service (SPS). Military users on the other hand, have access to the Precise Positioning Service (PPS). Ways to boost accuracy include the use of processed satellite orbiting data (post-processed satellite ephemerides) and

differential techniques (positions are derived relative to precisely surveyed points). The limited availability of the PPS to selected civilian users is much discussed. Accuracy is not the only controversy surrounding GPS. The question of user fees (none, for the time being) is an issue that will affect the operational success of the system. Lastly, as with all military systems, responsiveness to users and the question of control are major concerns.

Interestingly, there has been a recent announcement of plans for civil systems making use of both GPS-Navstar and the Soviet GLONASS (a GPS-like system, consisting of 12 satellites). Increased location precision is the motive.

3.2. QUALCOMM'S QASPR:

In February of 1990, Qualcomm, a provider of satellite communications services announced the introduction of the Qualcomm Automatic Satellite Position Reporting (QASPR) system to the U.S. market. That system was claimed to significantly improve the accuracy of position reporting when compared to LORAN-C systems. It had already been operating in Europe. QASPR is a part of Qualcomm's OmniTRACS system. It processes the signal from one satellite and monitors a beacon signal from a second satellite. It uses existing Ku-Band frequencies. A vehicle can be tracked 24 hours a day anywhere within the continental United States. Accuracy is claimed to be better than 1000 feet under any circumstances.

3.3. GEOSTAR'S RDSS PROPOSAL:

Geostar's founder, Gerald O'Neill, began development of a satellite based positioning system for transportation. By the time the company was formed in 1982, the project had evolved into a technology that seemed to suit the location needs of the trucking industry. It is still not fully operational. After the feasibility of providing communications relay from low power ground units was demonstrated, Sony and Hughes offered equipment using Geostar's services and frequencies. Until the full deployment of the system, LORAN-C receivers provide positioning. LORAN-C now covers the large majority of the inland United States.

Geostar emerged as a civilian alternative to the GPS. It not only managed to get FCC approval (and frequency allocation) for its private RDSS system, but the FCC adopted the Geostar technical design as its baseline (1984, reaffirmed in 1986). The FCC held the view that providing spectrum for an alternative system to GPS is beneficial in that services can be tailored to the needs of the market. This was despite the Federal Aviation Administration's (FAA) objections. FAA wished to use GPS as its building block for aircraft positioning, and seemed to be fearful of a competitive system.

FAA's main arguments were:

1. GPS allocates frequencies more efficiently since it uses only 2 MHz of bandwidth as opposed to 115 MHz for Geostar.
2. GPS being a broadcast system can serve an infinite number of users. Geostar's system is frequency limited since it both receives and transmits data via satellite and can only serve a certain number of users.
3. With GPS the user pays once to purchase the receiver and does not pay for the use of positioning information.
4. The presumption is that GPS will become the predominant technology. For this reason, there is the view that the cost of GPS receivers will drop substantially.

The Geostar system in its full implementation will be comprised of three geostationary satellites carrying the necessary transponders. They will be manufactured by GE and are scheduled to be launched by the mid 1990's. User terminals are active, i.e., both receive and transmit. Other than that, they may be relatively simple because they do not perform calculations or accurate timing functions. The operations center is in Washington D.C. It transmits precise timing signals. They are retransmitted by one of the three satellites. The signals are received by the user who synchronizes himself and transmits his own signal. This signal is picked up by all satellites and relayed back to the operations center along with other information such as user identity. When the signals reach the control station their travel time and other pertinent data can be extracted. This information is processed at the central facility and routed to fleet headquarters in the form of coordinates or proximity reports.

The major hurdle is that for other than a very coarse position fix, users have to input their geocentric height (not height above mean sea-level), information not readily available. This is true even when three satellites are used. To remedy this, Geostar obtained a patent in September 1989 for a system that according to company officials would indicate position within 2 to 7 meters, using a portable 20-ounce radio costing just several hundred dollars (assuming mass production). Accuracy would be achieved using a nationwide digital terrain map stored in a ground-based computer. Heights would be calculated from the terrain map starting with an initial position estimate and iterating a number of times. This "satellite compass" system would be user friendly and give position information in plain English, e.g., "You are 70 feet north of the intersection of East Road and West Street." The time for a fix would depend on the accuracy of the initial estimate. The system's accuracy has not been demonstrated yet, but the quoted 2 to 7 meters seem rather optimistic.

4. MOBILE COMMUNICATION SERVICES

Mobile communications services can either use a satellite or a terrestrial network. A satellite network can provide service to rural or other areas not covered by a terrestrial one. The latter is more advantageous in urban areas. Therefore, the two networks are seen in a complementary way and one would hope for an integrated telecommunications network. The systems that will be described below relay information from a vehicle to fleet headquarters and vice versa using a communications network. In addition to position information, all systems allow a certain amount of messaging. Some can transmit voice (Motorola), others plan to offer voice synthesis technology. Systems with limited potential when compared to fuller services (e.g., CB radio, paging) will not be considered in the following discussion. Some suppliers however, offer paging as a supplementary function. The driver, for example, in a restaurant can be alerted that a message is waiting in the tractor unit. Another vendor is offering a paging system, that allows drivers to take their messages at a truckstop from a voice-mail or "fax-mail" system.

4.1. SATELLITE BASED SERVICES:

The following discussion will concentrate on five service providers: AMSC (American Mobile Satellite Consortium), Qualcomm, Geostar (with units manufactured by Sony and Hughes) and INMARSAT. We start with AMSC although it does not yet offer satellite services to land mobiles because they only hold a licence for domestic MSS services. Qualcomm was first on the market with a two-way capability, Geostar has an RDSS licence and INMARSAT, an international organization, is trying to broaden its services to include air and land communications, in addition to maritime.

4.1.1. AMSC:

After several years of debate, the FCC ruled that in the U.S. a single service provider would be authorized to offer domestic mobile satellite communications. COMSAT, the U.S. INMARSAT signatory, would provide international services. Over the years, eight companies applied for licences, so the FCC mandated a consortium, the American Mobile Satellite Consortium or AMSC, which was given monopoly rights on certain frequencies allocated for MSS purposes. AMSC was also given the license to construct, launch, and operate a domestic mobile satellite system covering air and land and offering both voice and data. While the applications were pending however, both Geostar and Qualcomm, unfettered by the regulatory proceedings, went ahead with their own systems. Geostar had an RDSS licence and Qualcomm used Ku-band frequencies. Faced with such competition in the land mobile arena, it seems that AMSC has increased emphasis on aeronautical services.

According to company officials, AMSC will start offering some sort of vehicle tracking services to land mobiles before the end of 1991 using leased satellite capacity (INMARSAT's), and probably in cooperation with Telesat Mobile of Canada (a member of the AMSC consortium). Hughes Network Systems was awarded the contract for the ground facilities (operations control center, earth station control equipment, and 3,000 user terminals). Telesat Mobile of Canada has been offering in Canada a similar data-only service since May 1990. AMSC and Telesat Mobile plan a dedicated system covering both the US. and Canada for the mid 1990's. By then, AMSC's own satellites are expected to have been launched. Rockwell, a well known company in the trucking community, has plans to enter the satellite communications business with a system called SATCOM that will use the AMSC satellite services. Rockwell's on-board computer (Tripmaster) will be integrated in its system proposal.

4.1.2. Qualcomm's OmniTRACS:

Qualcomm is a privately held company. It manufactures, markets and services the OmniTRACS system. Its founders (Jacobs and Viterbi) are highly respected for their technical expertise and have pioneered many technological innovations. Among them are, the commercialization of small antennas (VSAT's) in 1980 and the development of the encryption technology that today is the accepted standard for use by satellite-delivered entertainment and information networks.

Looking for new opportunities, in 1985 Jacobs and Viterbi turned to the emerging mobile satellite technologies. They identified fleet managers as their potential customers. While others were seeking regulatory approval to offer satellite services to vehicles (RDSS or MSS) on L-band frequencies, they decided to use Ku-band frequencies. Ku-band communications are used extensively for telephone, TV, and private data networks. Ku-band components are mass-produced and relatively low cost communications services and equipment are available for Ku-band frequencies. There were many satellites already in orbit.

A problem to be solved, however, was the development of a specialized proprietary antenna. Available frequencies have become saturated with telephone and TV signals. Qualcomm had to develop "quieter" signals that would not interfere with the existing telephone or TV signals. The antenna had to be small to be mounted on trucks at a cost operators could afford. The particular combination of antenna characteristics had been previously deemed unattainable by the industry.

Qualcomm teamed with OmniNet which at the time had an RDSS licence from FCC. After some initial failures, an omnidirectional Ku antenna was developed supporting two-way data transfer, alphanumeric messaging, and position reporting. The antenna is a sophisticated aiming unit and is more complex than the one used with other systems.

However, its physical reliability was proved after a one million miles vibration test conducted at the Navistar Technical Center. Although Qualcomm started later than Geostar did, the architecture of its system allowed it to offer two-way services well in advance of Geostar.

The basic elements of the Qualcomm system are:

1. An on-board truck unit that serves as the interface between driver and dispatch. This unit consists of a portable computer with a keyboard and a 40x4 line display, an outdoor unit (antenna and front end electronics), and a communications unit. The message may be up to 2000 characters long. The communications unit used to contain the LORAN-C receiver but as mentioned earlier, Qualcomm now uses the QASPR system that determines positions by sending signals to and from Ku-Band transponders on two different satellites.
2. Ku-band transponders on GTE's GEOSTAR 1 satellite and back-up transponders have been reserved to guarantee operational redundancy. The location of the satellite ensures "view angles" of the entire United States and South East Canada. Each transponder can accommodate 50,000 vehicles at a data rate of 15,000 bits per second.
3. A Network Management Facility (NMF) in San Diego (an alternate control center will be established as well). All transmission traffic between truck driver and dispatcher is routed through this hub station. The facility uses terrestrial lines to communicate with the fleet operations centers.

All message traffic passes through the NMF. The NMF contains:

1. A large antenna and modems for communications with the mobile terminals via the satellite.
2. A Network Management Center (NMC) for network monitoring, control, message formatting, processing, management, and billing.
3. Landline modems for connection with Customer Communications Centers (CCCs) over dedicated or dial-up phone lines. As an alternative to terrestrial links, Qualcomm's Ultra Small Aperture Terminal (QuSat) may be used. This is a specialized VSAT antenna that can be used as a data link between dispatch computers and Qualcomm's control center or even between trucking companies and their customers.

Software from Qualcomm simplifies the interface between fleet computers and the OmniTRACS system. The software, Qualcomm Communications Manager (QCOM), is installed on the dispatcher's computer system and runs concurrently with existing applications. QCOM handles all communications with NMC. The user can receive or send messages and then continue working on the computer. Other features include: modification of preformatted messages, clustering of vehicles, date- and time-stamped message acknowledgement, separate handling of emergency messages, password

protection, automatic routing of messages to appropriate dispatchers, and vehicle database and position history. A program that can cooperate with QCOM is InTRACS/Atlas. This provides a color map showing the position of a trucking fleet's vehicles. With this system in place, the user can switch between applications software (word processing, spreadsheet, vehicle routing, etc.) and the color map with a single keystroke. Both packages run on IBM-PC compatible computers.

Besides messaging and positioning, other services offered by Qualcomm include trailer tracking and monitoring with TrailerTRACS. This is consisted of a transmitter mounted directly on the trailer and a receiver mounted on the tractor and connected to the OmniTRACS system. It gives carriers the opportunity to monitor the status, position and activity log of a trailer, assuming the tractor is connected to the OmniTRACS system. Temperature monitoring is also possible for refrigerated units. The software that makes use of TrailerTRACS is an integrated part of QCOM. Finally, the OmniTRACS Driver Pager, with a range of 1/2 mile around the truck makes sure that the driver will not miss an important message.

Outside the U.S. market, Qualcomm is currently operating 150 units in Europe after a series of successful demonstrations. It circumvented the regulated European telecommunications environment by offering no voice and using Ku-band transponders on satellites operated by EUTELSAT, a European telecommunications organization. The name of the system is EutelTRACS. Qualcomm also operates in Australia, and testing is underway in Japan where Qualcomm signed an agreement with C. Itoh and Co. Ltd and Nippon Steel Co., to form a joint venture to market and provide OmniTRACS systems and services.

4.1.3. Geostar:

Geostar, after having being granted operation authority on L-Band frequencies, started out to provide an RDSS system. In its full implementation the system will consist of three dedicated RDSS satellites. The so called System 3.0 is scheduled to become operational in the mid 1990's after GE manufactures the satellites. In the meantime, System 2C is available allowing two-way transmission of brief messages between a fleet dispatcher and a truck driver. LORAN-C is used for position purposes, pending full deployment of the RDSS system. Sony (2-Wayfarer) and Hughes (SkyRider) manufacture units making use of the Geostar services. As noted earlier, in its present status the system operates in a position-reporting mode with ancillary messaging capabilities.

The basic elements of the system are:

1. An on-board truck terminal with a keyboard and a display that serves as the interface between driver and dispatch, a LORAN-C antenna, a transmit/receive antenna, and a

transmitter and a receiver. Sony's receiver unit contains the so called Intelligent Interface Processor that allows interfacing with optional accessories. Earlier versions of Sony's and Hughes' equipment had one-way capability. After Geostar announced the availability of two-way services, both offered upgrades conforming to the specifications of system 2C. The message may be up to 100 characters long. Sony's display is 40x4 lines and Hughes' 20x4 lines.

2. Transponders are carried on GTE's Spacenet IIIIR satellite. Four back-up transponders guarantee operational redundancy. Company officials claim that system 2C is capable of transmitting 1 million messages per hour and that a maximum of 40,000 vehicles can be accommodated.
3. All transmission traffic is routed via a main control facility in Washington DC. While the facility communicates with trucks via satellites, it communicates with dispatchers via terrestrial lines. Another control center is planned in Montrose, Colorado.

Both Sony and Hughes offer or plan to offer an array of value-adding services similar to Qualcomm's, services such as trailer tracking, anti-theft systems, and engine monitoring. Software supplied with the systems simplifies fleet management.

Railstar Control Technology offers specialized services to the trucking industry. It uses equipment manufactured by either Sony or Hughes and adapts both hardware and software to serve specific needs. SCANTRAK, the name of the system, can also be used by other transportation modes.

Geostar is currently trying to expand its services in Europe and Australia through joint agreements. In 1987, Geostar and France's space agency CNES signed an agreement for a radiodetermination satellite system (called Locstar) totally compatible with Geostar's system and offering the same services. It will cover Europe, the Middle East, and Africa.

In late 1988, Geostar asked the FCC for permission to create a Digital Land Mobile Satellite Service (DLMSS). This was regarded as an attempt by Geostar to offer voice services. However, domestic mobile satellite services (including voice) are supposed to be offered by AMSC, the government mandated consortium. AMSC, as was expected, objected to Geostar's proposal for DLMSS, attributing the proposal to Geostar's poor financial results. Geostar's argument was that DLMSS's services would be digital and technologically new and therefore not covered by the FCC ruling that created AMSC. In addition, voice would only be offered as a much higher priced add-on.

4.1.4. INMARSAT:

INMARSAT's network of civilian communications satellites was intended for maritime traffic, and it provides ships with two-way voice and data communications (Standard-A terminal). A new low-cost terminal has been recently introduced (Standard-C) that allows

two-way low speed data communications with land mobiles (no voice). A market of the order of 250,000 Standard-C units is anticipated by INMARSAT. A low-cost telephony terminal (Standard-M) is in the development stage. INMARSAT's Standard-C has been successfully tested in trucks in Europe, but it has yet to gain the acceptance Qualcomm and Geostar enjoy, especially after both started expanding in Europe. INMARSAT has undertaken a series of experiments to determine the feasibility of interfacing a GPS receiver in a Standard-C terminal. In this configuration the system will not conceptually differ from previously described ones, except perhaps for enhanced messaging (storing-forwarding) capabilities.

INMARSAT does not sell its satellite capacity directly to the end users. It uses resellers instead, such as Geostar Messaging Corporation (subsidiary of Geostar), AMSC, and Telesat Mobile of Canada.

4.2. TERRESTRIAL SERVICES:

Two technologies will be outlined in this section. The first, meteor burst, uses properties of sand-sized particles in the atmosphere. Its main advantage is low costs. The second technology, cellular radio, has been growing fast in the last ten years and now is expanding to rural service areas.

4.2.1. Meteor Burst Technologies:

The use of meteor bursts is a newcomer to the field of mobile communications although the technology itself has been in existence for more than 20 years. Meteor-burst technology offers an alternative at almost half the price of satellite systems. Transtrack Inc., holds the first FCC license for marketing the service to the transportation industry and has already installed a number of units. Pegasus followed suit, emphasizing its ability to provide software compatible with carriers' management information systems. (However, it recently went bankrupt.) The in-truck terminal is similar to those used by Geostar and Qualcomm. LORAN-C is used for positioning. The system operates like the satellite based systems with an important difference: there is no satellite.

Enough sand-sized meteors enter the earth's atmosphere and vaporize each hour to produce a phenomenon known as meteor scatter: ion trails that can be used as reflective shields for FM radio waves. When a meteor trail appears in an appropriate part of the sky, the transceiver sends a burst of data it has been saving and the information is reflected to a base station. During the same time period the truck receives data from the base station. The base stations are connected by terrestrial links to a network operations center and from there to fleet dispatchers. Transtrack operates seven stations.

Besides the lower cost, another advantage over satellite communications is the theoretically increased reliability because there is no space segment: all of the support equipment is on the ground. Messages, however, have to be short, only 32 characters long. Messages are constrained by the size of the burst, although longer messages can be linked over several bursts. Furthermore, satellite messages can be transmitted in as little as 15 seconds, while meteor bursts require several minutes (depending on the availability of a meteor burst). Time requirements do not facilitate interactive dialogue.

4.2.2. Cellular Radio Technologies:

The common problem with cellular radio systems is that normally they allow “roaming,” that is, calling from a city covered by a system other than your own, to a very small extent. Another problem is capacity, but the advent of digital cellular and new ways of multiplexing the signals will significantly increase the efficiency of frequency reuse between adjacent cells as well as the capacity of a single channel. One company offers nationwide service to purchasers of the Cummins Truckphone. After the introduction of the “following-me roaming” service, one does not have to know where the vehicle is before one calls the driver.

Motorola is currently expanding its voice and data mobile communications system called CoveragePLUS. It is a two-way radio, to which a position finding receiver may be interfaced (for the time being this is a LORAN-C receiver; later it will be a GPS receiver). Motorola is linking together trunked specialized mobile radio systems to allow conversation between fleet headquarters and drivers. Features include voice communications (talk and listen simultaneously), increased privacy, the designation of “talk groups,” roaming, preset messages, and an optional text terminal with a 1920 character storage capability. It is anticipated that transmission towers will soon be installed in all major traffic corridors (company officials claim that 512 sites identified as priority routes will be covered by the end of 1990). The towers define zones within which the vehicle can be located. Thus, the user does not have to opt for the more expensive LORAN-C receiver unless there is a need for increased positional accuracy. Software on a personal computer displays vehicles on a map in real time and facilitates communications.

The use of voice processing systems has been growing lately. Initially used by telephone companies (voice-mail) and banks (automated balance information) to increase customer service, there is at least one company selling a similar system to the trucking industry (Computer Communications Specialists). The driver calling from either a regular or cellular phone can not only access the firm’s database but modify information stored in it as well. In its current configuration the system is not linked to any of the positioning systems discussed so far and is geared toward small scale regional operators.

5. NEW SYSTEM CONCEPTS

For some years, NASA has been developing an Advanced Communications Technology Satellite (ACTS). The program has overcome development barriers, and currently NASA is trying to find private-sector experimenters for the two-year demonstration phase of the satellite's four year life cycle. Launch is scheduled aboard the Space Shuttle for May 1992. The ACTS is being touted as a telecommunications problem-solver thanks to its new and sophisticated technology. The technology offers the possibility of hybrid digital networks linking satellite, fiber optic, and coaxial cable systems. The availability of various data rates could provide user access to a full spectrum of video, voice, and data services. Use of the Ka-band has the potential to greatly enlarge the market for mobile communications. Recently, NASA announced that efforts toward the development of a new type of mobile terminal have been initiated. Whether these services will be commercially feasible will have to be determined by a demonstration phase.

Finally, there is much activity surrounding the so called "wireless" communications technologies. Two system proposals are frequently mentioned. One is from Motorola, announced in June 1990. Named "Iridium" it is expected to become operational before the end of the century. A call from any portable cellular phone, anywhere in the world and possibly outside the range covered by existing networks, will be routed through a constellation of 77 low-orbit small satellites. The system will use digital switching and transmission to handle both voice and data. Although Iridium will operate at different frequencies than existing cellular systems, it will be made compatible to them. Motorola expects the mobile and portable terminals that it will manufacture to cost around \$3,000. Currently, the company is searching for partners to help finance the effort.

Many telephone and communications companies are experimenting with wireless terrestrial technologies that could lead to the next generation cellular system or to replacing hardwire networks. The new "personal communications networks" use pocket-size, cordless handsets that function much like cellular phones. A system of low-power, high-frequency transceivers would be deployed around cities to transmit and relay calls. The new systems are expected to require less power than cellular systems allowing for lighter phones and opening up the doors for the so called "pocketphone services". The base stations would be at closer intervals than present cellular systems that use powerful radio towers. The German Telecommunications authority (DBT) will deploy a network of towers to cover the whole country by 1994, using technology supplied by Motorola. The latter agreed to open up its communications protocol to third parties that will offer terminals and software. Each tower will cover an area of 8 to 15 km. A demonstration has been scheduled for March of 1991. A similar voice and data system is also available in Hong Kong (by Hutchinson Mobile Data) and is used in a variety of applications (courier services, personal communications, horse race betting). The U.K. is also very active in this area with at least five different small scale systems in operation. Similar experiments are underway in the

United States also.

6. THE CURRENT PROJECT - TASKS

Although information has been presented in terse fashion, the discussion above indicates diverse and changing activities by equipment suppliers and actors offering services. It indicates potential for further development and use of systems. Project objectives follow from this observation. We seek to identify opportunities for the trucking industry and assess implications for IVHS. The project is anticipated to last ten person months. The first activity is the preparation of this discussion paper updating previously gathered information and suggesting future research tasks. It will be circulated among “experts” and the tasks modified as needed.

The following sections outline the proposed research tasks. Eight tasks are grouped in five categories.

6.1. MONITORING OF THE TECHNOLOGY:

Building from previous work, a continuing task will be the monitoring of the technologies. The baseline survey of the location and communications technologies already performed will be continuously updated as new information becomes available. Ongoing through the project, technological developments in the U.S., Europe and Japan will be monitored. Particular emphasis will be given to systems suitable for regional and local area uses. Cellular radio systems will be examined. The technology review will not be restricted to commercially available systems. Technological trends and new system concepts that might affect the positioning and/or communications field in the next decades will be identified and their impacts will be speculated upon. Competitive and complementarity issues among different systems will also be addressed. These are influenced by factors such as the geographical spread of the market a carrier is serving, the regularity of its route, and the kind of cargo it is transporting.

Following the activities of the Federal Communications Commission (FCC) is the second task ongoing through the project. The FCC is the regulatory authority for the communications industry and the impacts of its actions will be evaluated.

6.2. MONITORING THE ADOPTION PROCESS:

Preparing a questionnaire to assess in a systematic way the rate of adoption, technologies used, applications, and benefits perceived by both shippers and carriers, is the third task. Contacts will be established with representatives covering all aspects of the

business. The questionnaire will be tested and then executed (fourth and fifth tasks).

6.3. IMPLICATIONS FOR THE TRUCKING INDUSTRY:

The core processes of a trucking company will be considered, as well as the flow of information from one organizational unit to another and from company to company. Then, potential impacts and opportunities arising from the new technologies will be suggested (sixth task). The fourth and fifth tasks will support this analysis.

6.4. IMPLICATIONS FOR IVHS:

Trucks and passenger cars share the same guideway. Developments affecting truck operations cannot but be of interest to highway operators, especially in light of the IVHS research and opportunities. This part of the project will examine how IVHS work can benefit from truckers' extensive use of positioning and telecommunications equipment, and indicate opportunities for broad scale system implementation (seventh task). In late 1990, the demonstration phase of the HELP/Crescent project will start, involving at least 4,000 transponder-equipped trucks. This task will consider possible interrelations with HELP developments.

6.5. FINAL REPORT:

A final report will be prepared, interpreting and analyzing the findings of the research (eighth task).