Attachment 3

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Automated Collision Notification (ACN) Field Operational Test (FOT) Final Report

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16. Abstract

The goal of Automated Collision Notification (ACN) Field Operational Test (FOT) was to design, develop and field test new technology to automatically detect and characterize potential injury-causing vehicle crashes and then provide 9-1-1 dispatchers with information about the crash events The effort resulted in the development of specialized ACN equipment This equipment was designed to be easily installed in vehicles and to operate independently of existing vehicle safety systems. The design integrated commercially available accelerometers, cellular communications equipment, Global Positioning Satellite receivers, and automated map display technologies. A critical component of the system was the crash recognition and characterization software that analyzed crash forces in real time to determine when thresholds indicating the likelihood of serious injuries were exceeded.

The primary objectives of the FOT were to: 1) Identify and evaluate technical issues associated with ACN system reliability, effectiveness, and performance; 2) Evaluate deployment issues relating to the use of ACN systems by Emergency Medical Service and Public Safety agencies, and 3) Collection of data to evaluate the potential benefits of the ACN system.

To achieve these objectives a plan was executed with the following elements: 1) design and development of hardware and software that could reliably sense vehicle crashes that are likely to cause injuries and initiate automatic notification procedures, 2) recruitment of volunteers, 3) design, development and installation of communications, special processing, and display hardware and software, and 4) establishment of data collection procedures

The principal measure of performance was whether the use of ACN systems would reduce the time for delivery of medical care to victims of motor vehicle crashes. Baseline (non-ACN) response time data were collected to compare to the response times of crashes involving the ACN system.

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AUTOMATED COLLISION NOTIFICATION (ACN) FIELD OPERATIONAL TEST

FINAL REPORT

Cooperative Agreement DTNH22-95-H-07429

31 October 2000

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Prepared For:

National Highway Traffic Safety Administration (NHTSA)

Project Partners:

NHTSA, Veridian Engineering, Erie County Medical Center Department of Emergency Medicine, Erie County Sheriff's Office, Rural Metro Medical Services of Western New York, Cellular One, State University of New York at Buffalo Department of Industrial Engineering, Erie County Department of Emergency Services, Johns Hopkins University Applied Physics Laboratory

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List of Acronyms and Abbreviations

ACN	Automated Collision Notification
CET	Crash Event Timer
CETs	Crash Event Timer(s)
ECMC	Erie County Medical Center
ECSO	Erie County Sheriff's Office
FOT	Field Operational Test
GPS	Global Positioning Satellite
IVM	In-Vehicle Module
JHU	John Hopkins University
MERS	Medical Emergency Radio System
NHTSA	National Highway Traffic Safety Administration
PDOF	Principal Direction of Force
PSAP	Public Safety Answering Point
RCU	Reference Correction Unit

1 Introduction

The final results of the Automated Collision Notification (ACN) Field Operational Test (FOT) are summarized in this report The FOT began in October 1995 and was completed in September 2000. This program was an ambitious Field Operational Test that was conducted in Western New York by a private-public partnership under the direction of Veridian. The purpose of this report is to provide a high level summary of the program, its objectives and test results. During the conduct of the program a significant body of documentation was generated. These documents provide detailed information on the program. A bibliography identifying these papers and presentations is provided in Section 6 of this report. In addition, specific test data are presented in the appendices. Appendix A contains Newsletters that were issued during the project. Appendix B presents data for each of the specially equipped vehicles that were involved in a crash during the program.

2 Overview

2.1 Project Partners

The ACN Project would not have been possible without the cooperation and hard work by a team of private and public agencies, including:

- National Highway Traffic Safety Administration
- Veridian Engineering
- Erie County Medical Center, Department of Emergency Medicine
- Erie County Sheriff's Office
- Erie County Department of Emergency Services
- Cellular One (now Cingular)
- State University of New York at Buffalo, Industrial Engineering Department
- Rural Metro Medical Services of Western New York
- Johns Hopkins University (JHU), Applied Physics Laboratory

2.2 Project Overview

The goal of this FOT was to design, develop and field test new technology to automatically detect and characterize potential injury-causing vehicle crashes and then provide 9-1-1 dispatchers with information about the crash events. It is important to recognize that the ACN Project was initiated in 1995. At that time no commercial Mayday systems, such as Ford RESCU or GM's OnStar, were available, or announced. In that regard, the ACN Project provided the first opportunity to demonstrate and evaluate ACN/Mayday technologies in real-world environments The effort resulted in the development of the Veridian Automated Collision Notification (ACN) equipment This equipment was designed to be easily installed in vehicles and to operate independently of existing vehicle safety systems (e.g., airbags). The design integrated commercially available accelerometers, cellular communications equipment, Global Positioning Satellite (GPS) devices, and automated map display technologies. A critical component of the system was the crash recognition and characterization software that analyzed crash forces in real time to determine when thresholds indicating the likelihood of serious injuries were exceeded A patent was granted to Veridian for the development of the crash recognition algorithm (U. S Patent No 6,076,028).

The primary objectives of the FOT were to:

(1) Identify and evaluate technical issues associated with ACN system reliability, effectiveness and performance,

(2) Evaluate operational deployment issues relating to the use of ACN systems by Emergency Medical Service and Public Safety agencies, and

(3) Collection of data to evaluate the potential benefits of the ACN system.

To achieve these objectives a plan was proposed and executed that involved the following elements. 1) design and development of hardware and software that could reliably sense vehicle crashes that are likely to cause injuries and initiate automatic notification procedures; 2) recruitment of 1000 volunteer FOT participants and the schedule and installation of ACN equipment in their automobiles, 3) design, development and installation of communications, special processing, and display hardware and software at two Public Safety Answering Point (PSAP) locations within Erie County, one at the Erie County Sheriff's Office, and one at the Erie County Medical Center's Medical Emergency Radio System (MERS) dispatch center; 4) establishment of procedures to collect the data needed for evaluation when an ACN-instrumented vehicle was involved in a crash. These procedures included the use of experienced accident investigation teams to inspect all instrumented vehicles involved in crashes and to reconstruct the crash events; interviews of police, EMS, dispatchers, and fire/rescue personnel; the collection of notification and response times of emergency services; analyses of dispatcher emergency message records as well as the medical records of injured vehicle occupants.

The principal measure of performance was whether the use of ACN systems would reduce the time for delivery of medical care to victims of motor vehicle crashes. Baseline (non-ACN) response time data were collected to compare to the response times of crashes involving the ACN system. The baseline data were collected with Crash Event Timers (CETs) that were installed in the automobiles of a second set of volunteers from the test area. These CETs, which were also developed during this program, only measured the elapsed time from when a crash occurred. By providing an accurate crash time they enabled the accurate reconstruction of post-crash event timelines for crashes involving non-ACN equipped vehicles. The post-event crash timelines for ACN crashes and non-ACN crashes could then be compared

The ACN project proceeded through several phases, namely:

- System Design and Test – During this first phase of the project, the ACN crash sensing and communication equipment were designed and tested using lab and prototype implementations. This included the following equipment:
  - In-Vehicle Module (IVM) – Integrated crash sensors, GPS receiver, micro-processor, and cellular transceiver, which functioned to sense crashes in all directions, to determine whether the crash was severe enough to pose a risk to vehicle occupants and generate a data message that was sent via cellular phone to the 9-1-1 dispatch center. Specialized software was developed to determine when thresholds indicating the potential for injuries were exceeded.
  - Crash Event Timer (CET) – Inexpensive timers that used an inertial switch to detect when a crash had occurred and start the operation of the timer. At some time after the crash (perhaps, weeks later), investigators could access the car and read the CET to determine the elapsed time since the crash and then calculate the absolute time of the crash. CET times, together with times of post crash events obtained from 9-1-1 and Emergency Service records made it possible to calculate post-crash-event elapsed times.
  - Dispatch Equipment – PC-based system that integrated commercial off-the-shelf hardware and software with ACN message reception and display software. This equipment received emergency messages from the in-vehicle equipment, sounded an alarm, and displayed this information to 9-1-1 dispatchers for emergency response action. This equipment also forwarded the crash data to a secondary PSAP and allowed dispatchers to fax data to other PSAPs. Conference calls and forwarding of the voice portion of the call were also available as needed.
- Manufacture – This included fabrication of all ACN system hardware components including over 4,000 CETs, more than 1,000 IVMs, and three dispatch workstations.
- Test Implementation - This included all operational test planning and preparation activities such as: the development of strategies to recruit participants, preparation of recruiting materials (e.g., application forms, disclosure statements), recruiting and installation of ACN and CET equipment; installation of dispatch systems at the Erie County Sheriff's Office and Erie County Medical Center; and definition of data collection protocols.
- Test Operations - This included managing the data collection activities associated with ACN and CET crashes, maintaining and upgrading in-vehicle equipment with the latest software releases, communicating with test participants, monitoring the ACN dispatch centers and the ACN/CET "hotline" for reports of crashes, and maintaining participant and system evaluation databases. Other activities included organizing crash investigations, performing simulated crash tests, and coordination with local emergency service agencies.

- Evaluation - This involved evaluation of ACN performance in the operational environment. All crashes involving CETs or ACNs were investigated. Data were collected and used to reconstruct the crash, characterize the extent of injuries, and construct a timeline of emergency response actions.

A diagram presenting an overview of the ACN system operation is shown in Figure 2-1. The system was designed so that when an ACN equipped vehicle was involved in a crash, the following events occurred:

1) In-vehicle equipment sensed the crash by processing data from the unit's triaxial accelerometers,
2) The in-vehicle computer constructed a crash message containing information characterizing the crash, the vehicle location, and direction of travel prior to the crash;
3) The in-vehicle computer established control of the cell phone transceiver and initiated a call to the 9-1-1 PSAP operated by the Erie County Sheriff's Office;
4) Once the call was received the crash data was transmitted and displayed on the PSAP ACN computer;
5) Upon completion of the crash data transfer (approximately 5-10 seconds) the call was automatically switched to a voice mode and dispatchers could attempt to talk to the vehicle occupants;
6) Computers at the Sheriff's PSAP were programmed to automatically transfer the ACN crash message to the PSAP co-located in the Emergency Department at Erie County Medical Center. The most highly trained medical emergency dispatchers in the county were on staff at that location and were available to provide instructions and assistance to crash victims, should they be required. Additional details about the functioning of the ACN system are presented in the first ACN Interim Report [Benz et al., 1997]

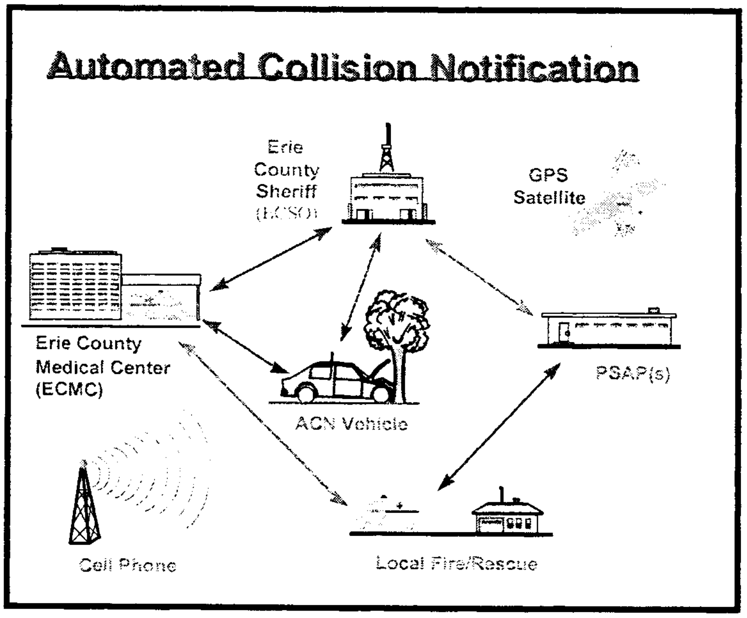

Figure 2-1. ACN Operational System Overview

2.3 Overview of Results, Accomplishments and Findings

This section provides a brief summary of ACN program accomplishments and results Additional information and data obtained during the program are provided elsewhere in this report. Specific accomplishments achieved during the program include the following:

- Designed, developed, built, and deployed an ACN crash detection and notification system The ACN equipment is capable of detecting crashes including rollovers. It is vehicle independent (i.e., it can be installed in most vehicle makes and models (both new and old) and does not require connections or interfaces with any of the vehicle safety systems) and is easy to install. Of particular significance is the fact that it incorporates an algorithm that permits the system to distinguish between crashes likely to cause injuries and all other driving events. The crash detection software that was developed during this program has been awarded a U.S. Patent.
- Recruited more than 700 volunteer participants and deployed the Automated Collision Notification (ACN) System in their vehicles.
- Developed and installed equipment into two Public Safety Answering Points (PSAPs) to display incoming crash messages from ACN equipped vehicles. These systems employed Geographic Information Systems (GIS) to display crash location and provided the ability to forward emergency data and voice to secondary PSAPs using fax and landline phone. The system automatically determined the appropriate secondary PSAPs based on the crash location.
- Developed and deployed over 3,000 crash event timers (CETs) in privately owned vehicles. The CETs were used to collect baseline crash notification and response event times for crashes that occurred in the test area and involved vehicles that did not have ACN equipment The CETs were designed to start a timer when a crash was detected. The timer was then read during post crash investigations to determine the exact crash time. Using the accurate time of the crash and other available police, EMS and 9-1-1 records, it was possible to construct accurate post crash event timelines (i.e., elapsed time from crash to 9-1-1 notification, elapsed time from crash to EMS dispatch, etc.). These event timelines were then used as a control in comparisons with ACN crash timelines.
- Coordinated the operational test during the 3-year period of ACN deployment. This effort involved overall test coordination, equipment maintenance, collection of test data, and coordination with the independent evaluator and all public and private test organizations The activities included administration of surveys and questionnaires, and the conduct of detailed analysis and reconstruction of all crashes experienced during the test. A database was developed to service all of the collected test data and support the evaluation analysis
- Raised public and professional awareness about ACN technology and its promise to improve the delivery of emergency services to crash victims. The project produced over 15 published papers and over 10 technical presentations at professional conferences. In addition, Good Morning America (Monday May 18, 1999), Dateline NBC (Sunday Oct 17, 1999) and the Osgood File (CBS Radio Network, May 12, 1998) broadcast stories on national networks describing the program and ACN technology These stories resulted in numerous additional newspaper articles and local television and radio interviews and stories.

A relatively small number of personal injury crashes (i.e., 15 ACN crashes and 26 CET crashes) were experienced during the FOT. These crashes, and the experience gained during three years of field tests permit several observations to be drawn from the program, namely:

- ACN technology works. It is possible to detect crashes, characterize their location and severity; automatically generate messages with detailed crash information; and transmit the messages to PSAPs using existing cellular communications infrastructure.
- Automatic notification of crashes reduces emergency service response times. It is possible to provide quicker emergency services to crash victims by consistently providing crash notification messages, with accurate location, to PSAPs within one or two minutes of the crash. .
- PSAP personnel were able to successfully adapt to their procedures to use the ACN system to improve dispatch operations
- Widespread deployment of ACN technology will require successful application of commercial models. ACN works when people put it in their cars. This will be achieved when ACN systems are made available through successful commercial offerings
- Integration of commercial ACN systems with the public infrastructure (9-1-1 system, etc.) is crucial to achieving maximum ACN benefits. The ability to deliver ACN emergency data electronically to the correct PSAPs avoids time-consuming and error-prone verbal protocols in use today Integration with PSAPs is critical to ACN success.

- Emergency service agencies participating in the program recognized that the data available from ACN systems promise to provide a wide range of benefits beyond reducing notification and response times. The potential benefits of ACN crash-related information include support for the following: decisions concerning equipment that may be needed at the crash scene (e.g., helicopter, jaws of life, multiple ambulances); preparations by EMS staff for on-scene interventions and support, triage decisions; and preparations at emergency medical and trauma care facilities for the arrival and treatment of crash victims.
- The availability of a voice connection between the PSAP and the distressed vehicle provides important advantages over data-only systems. It allows dispatchers to verify that emergency services are required and to obtain additional information that may assist in making response decisions and setting priorities.
- Knowledge of direction of travel can offer important information about emergency response execution. For example, by knowing direction of travel the fastest response route to incidents on divided highways or at overpasses can be determined.
- The conduct of large field tests provides numerous institutional, organizational and management challenges. Tasks such as the recruitment of participants, distribution and tracking of deployed equipment and correlation of subscriber records with the cellular service provider required significantly more time and energy than was anticipated at the beginning of the program.

The conclusions section of this report contains additional information and discussion on program results and observations.

While the ACN Project is complete, the work started during this project is continuing. Commercial Mayday providers are upgrading their systems and expanding their deployed base. The US DOT led National Mayday Readiness Initiative (NMRI) is working to facilitate the integration of ACN systems with the public infrastructure and 9-1-1 Standards setting bodies are developing, and building consensus for, standard communication protocols The ultimate goal of these efforts is the widespread deployment of ACN equipment and capabilities, and integration of this technology with the national and local public safety infrastructure

3 Project Description and Results

3.1 IVM and CET Installation Summary

3.1.1 IVM Installations

The installation of In-Vehicle Modules (IVMs) started in June 1997 and continued through the August 2000. In August of 2000, IVM installations were terminated and the elimination of active units in the field began by remote disabling of the ACN in-vehicle system The inactivation process occurred when an ACN unit called Veridian Engineering for its bi-monthly check-in. After deactivation the cellular telephone equipment remained functional but the ACN crash recognition components were disabled. The deactivated units have been abandoned to the participants to use as cellular telephones or to remove and dispose of as they wish. If participants request that Veridian Engineering remove the units, we have done so and disposed of the hardware

Figure 3-1 shows the net number of IVMs installed each month during the FOT (after attrition) and the resulting total number in the field through 1 August 2000. It was originally planned to have 1000 ACN equipped vehicles in the field for one calendar year for a total of 1000 vehicle years-in-the-field. Because of difficulties involved in participant recruitment, installation, maintenance, and attrition this plan was modified. Intensive recruitment and installation efforts resulted in an active fleet of almost 700 vehicles in the field at the beginning of 1999. It can be seen in Figure 3-1 that over the last year of the FOT the active participants slowly decreased from this maximum to approximately 550 as the number of participants leaving the program exceeded the number joining the program. This occurred because active recruitment of new participants effectively stopped at the end of 1998

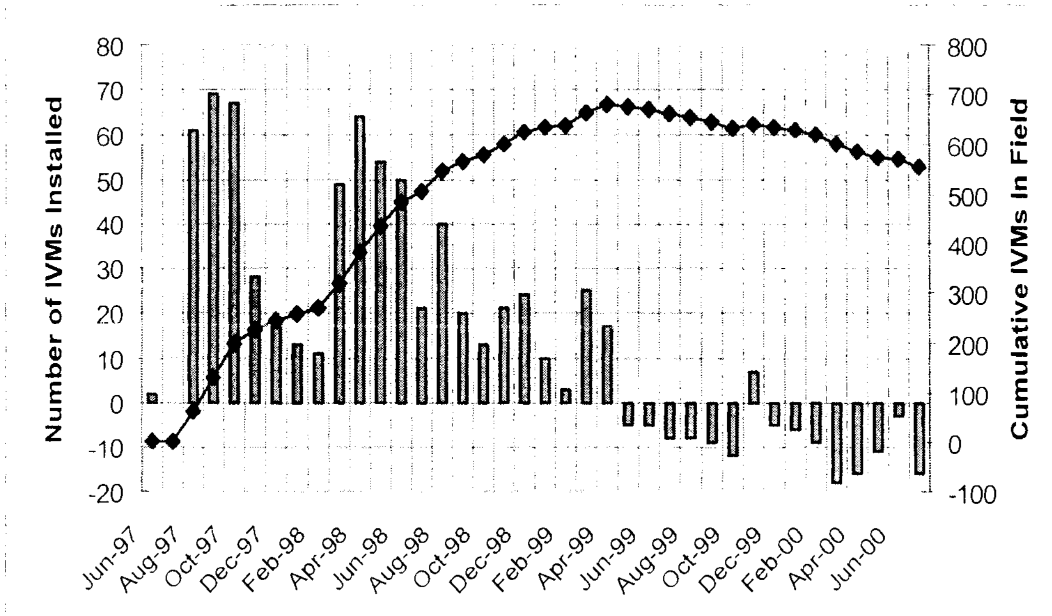

Figure 3-1. Net IVM Installations/De-installations by Month (bars) and Total IVMs in Service

Figure 3-2 shows the cumulative number of ACN days-in-the-field for the FOT. As noted, by 1 August 2000 the program had achieved 554,855 ACN days-in-the-field, or 1520 ACN years-in-the-field. This represented an increase of about 50% over the original program goal.

Over 300 IVMs were removed from vehicles after crashes or for maintenance purposes during the duration of the FOT. They were generally replaced with a new ACN in-vehicle module. Some of these units were defective, some required repair, and others needed a thorough checkout to determine their suitability for reuse. There were sufficient IVM units fabricated so that none of the units removed from service were needed for reinstallation.

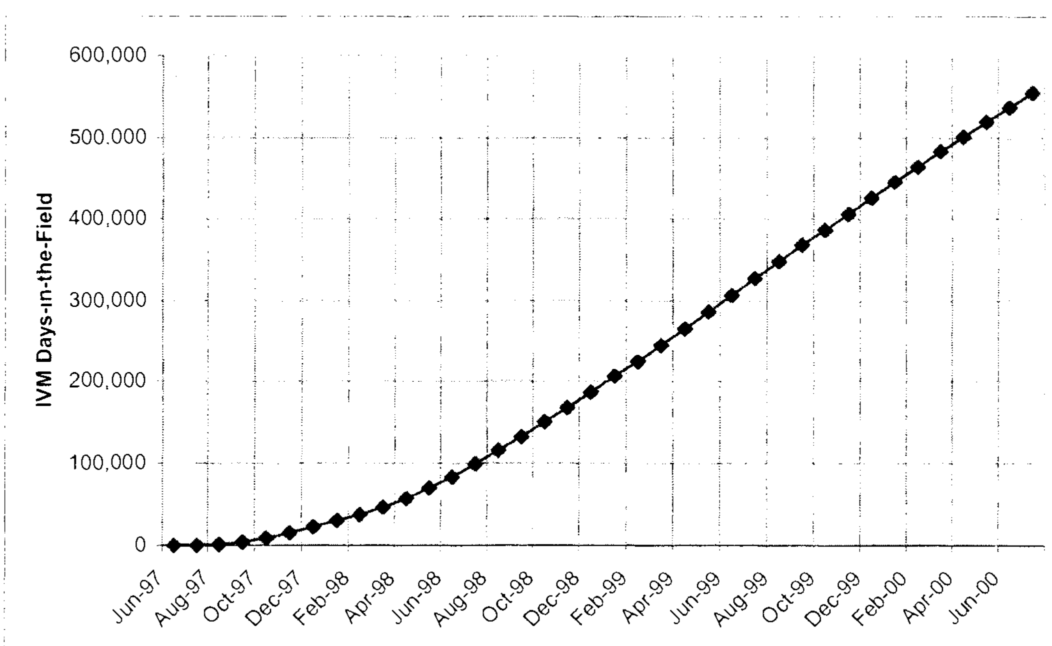

Figure 3-2. IVM Days-in-the-Field

3.1.2 CET Installations

The installation of Crash Event Timers (CETs) started slowly in July 1996 and ramped up to a relatively high installation rate during 1997 At the end of 1997, 2,570 CETs were installed and registered (i e , paperwork returned and installation recorded in the CET participant database) Since 1997, CET installation continued at a slower pace By the end of the program, 3,316 CETs had been installed That number included 347 that were assumed installed but for which paperwork was not returned These were CETs for which the installing agency (1) provided verbal confirmation of the installations but was not able to provide installation documentation and (2) had a sufficiently successful record of CET installation that their claim was judged to have credibility

Over 700 CETs were issued to organizations and were not installed or were returned to Veridian Engineering Most of these are believed to have been lost

The number of CETs in service and the monthly installation and de-installation of CETs over the program is depicted in Figure 3-3 Figure 3-4 shows the cumulative CET days-in-the-field Figures 3-3 and 3-4 are both based on data from the participant database and do not include CETs that were assumed to be installed and does not include those that left the program without notifying us

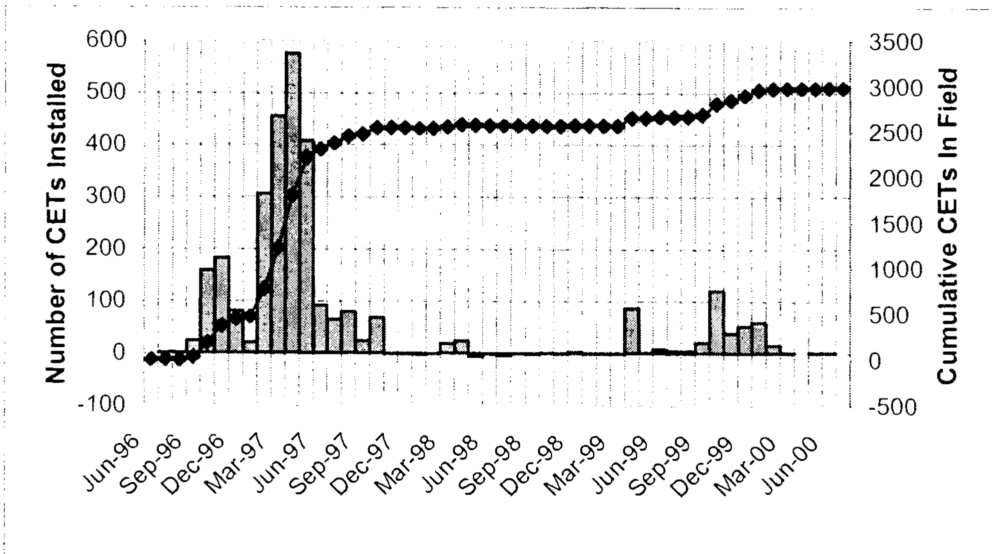

Figure 3-3. Net CET Installations/De-installations by Month (bars) and Total CETs in Service

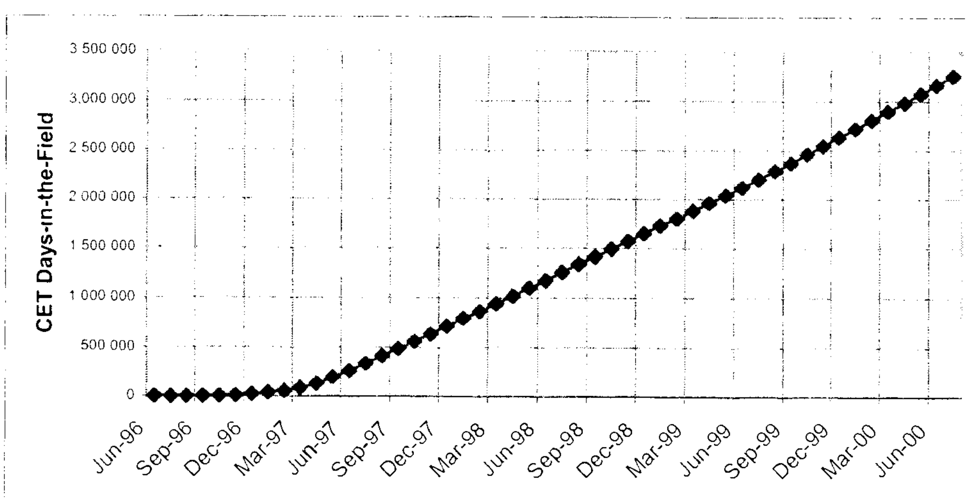

Figure 3-4. CET Days-in-the-Field

The exact number of CETs actively involved in the test was always uncertain because it was not possible to account for participants who moved or sold their vehicles. A sample of CET participants were surveyed in the summer of 1999 to obtain an estimate of the percentage that had either left the test area or sold their vehicles. Table 3-1 summarizes the results of this CET participant survey. If these results were representative of the full CET fleet, the active CET test sample as of September 1999 should be discounted by about 30%.

Table 3-1. Results of CET Participant Survey

	Number	Percent
Attempted to Contact/Survey	**97**	**100%**
Total Surveyed	46	47%
Total Surveyed	**46**	**100%**
Remembered the CET program	42	91%
Vehicle still in Western NY	33	72%
Still owned the vehicle	31	67%
Knew the CET was attached	30	65%
Knew the window sticker was attached	30	65%
Involved in Crash	7	15%
Involved in Crash	**7**	**100%**
Did not report crash to Veridian Engineering	3	43%
Did not report crash to Veridian Engineering	**3**	**100%**
Forgot to report	2	67%
Tried to report but found voicemail confusing	1	33%
Unaware it was their responsibility	0	0%
Assumed someone else would report it	0	0%

3.2 Participant Outreach

The success of the ACN test depended on the continued support and motivation of the test participants/volunteers In order to keep participants motivated, and to remind them of their commitment to the test, we periodically issued Newsletters These were sent to all ACN and CET participants. They served several purposes First, they thanked participants for their participation and continued support of the program Second, they provided a summary of the results of the program, citing example crashes and a summary of the total numbers of crashes. By providing a summary of test results, it was hoped that participants' motivation and interest in the program would be maintained at a high level. Third, the newsletters provided participants with important information about the program (e g., test extensions) and reminded them about their responsibilities (e.g., to call the ACN 1-800 number to report crashes or problems). Finally, the newsletters served as a mechanism for continued solicitation of additional applications for participation. Appendix A includes the ACN and CET newsletters sent to all participants. These newsletters are reproduced in Appendix A.

3.3 ACN and CET Crashes

Table 3-2 summarizes the overall ACN and CET installations and crash investigations during the project This summary includes the number of units installed and the number of above and below threshold crashes experienced

Table 3-2. Summary of ACN and CET Installations and Crashes

	ACN	CET
Recruiting and Installation		
Total Installed During Program	874	3,316
Peak Base Installed at Single Point in Time	680	N/A
Days-in-Field (rounded)	555,000	3,254,000
Operational Test		
Total Crashes	70	76
Below-Threshold Crashes	48	40
Above-Threshold Crashes	22	36
Not Notified (False Negative)	5	5
Not Investigated*	2	5
Investigated	15	26
Crashes with Injury	9	16
Crashes with EMS Response	8	15
Crashes with EMS Transport	8	8
Occupants in Crashes	51	69
Occupants with Injury	17	24
Maximum AIS in Crashes	3	2
Min Notification (rounded)	0 min	0 min
Max Notification (rounded)	2 min	46 min
Out of Study Area	2	5
Delayed Notification	7	7
False Notifications (# of ACN units)	31	N/A

*Crashes that were not investigated include: one ACN and two CET crashes that occurred significantly outside of the study area, one CET crash in which the CET was missing from the vehicle, one CET crash with delayed notification (the timer had already reset) and one CET crash that was not police-reported One ACN crash could not be fully investigated because the participant would not cooperate with the investigation

As noted in Table 3 2, a total of seventy ACN crashes occurred over the duration of the program, twenty-two of these were above threshold crashes of which five did not call the Sheriff (see Section 2 5 for a discussion of false negative crashes) Two crashes were not investigated and forty-eight were below the crash detection threshold

A total of seventy-six CET crashes occurred over the duration of program Thirty-six of these were above the crash detection threshold Of these there were five crashes in which we never received notification and five crashes that were not investigated because they occurred out of the test region Forty crashes were below the crash recognition threshold leaving twenty-six CET crashes for which a full investigation was performed

A summary of ACN and CET crash totals is presented in Table 3-3

Table 3-3. Number of Crashes

	ACN Crashes	CET Crashes
Total Crashes	70	76
Below Threshold	48	40
Above Threshold	22	36
▪ Not Notified	5	5
▪ Not investigated	2	5
▪ Full Investigation	15	26

A map of the locations of all of the ACN and CET crashes is shown in Figure 3-5.

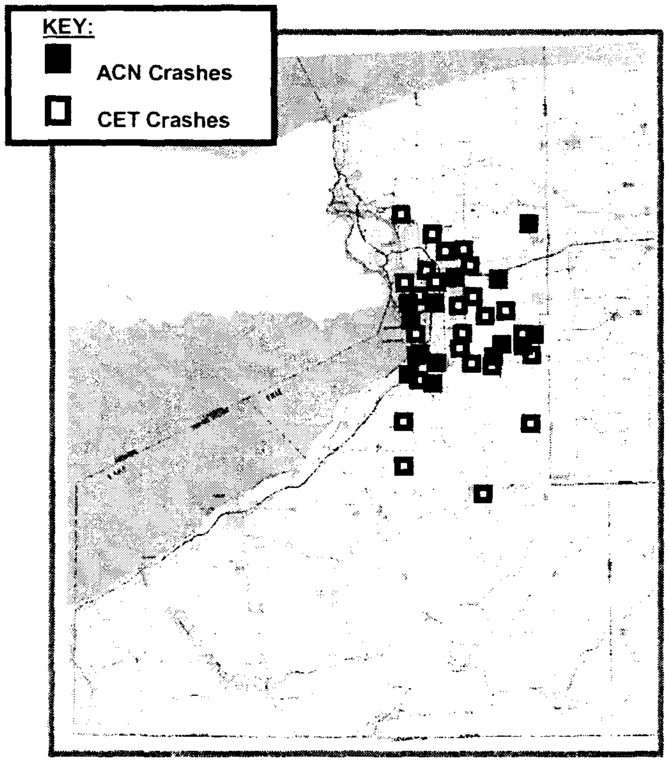

Figure 3-5. Locations of ACN and CET Crashes Experienced During the FOT

3.3.1 ACN Crashes

Figure 3-6 shows the temporal distribution of ACN crashes during the ACN FOT. It graphically shows crashes according to the following definitions:

- Crashes – Crashes that were above the threshold for alerting Sheriff dispatchers and that were correctly and successfully reported by the ACN System. The ACN crash threshold was designed to make an emergency call for crashes likely to produce AIS ≥ 1 injuries.
- Incidents – Crashes (manually reported) that were below threshold (e g , fender benders) for which the ACN System correctly did not send an automatic crash notification.
- Not investigated – One crash that occurred far outside the ACN test area and was not investigated Also one crash in which the driver of the ACN vehicle (a young adult whose parent had volunteered to be a participant) would not cooperate with investigators and the crash was not investigated.
- False negatives – Crashes that were above threshold (as determined by post crash reconstruction) but for which Central Dispatch was not automatically notified by our system (a missed crash). This includes cases where there was no cellular coverage and where the IVM apparently was damaged during the crash.

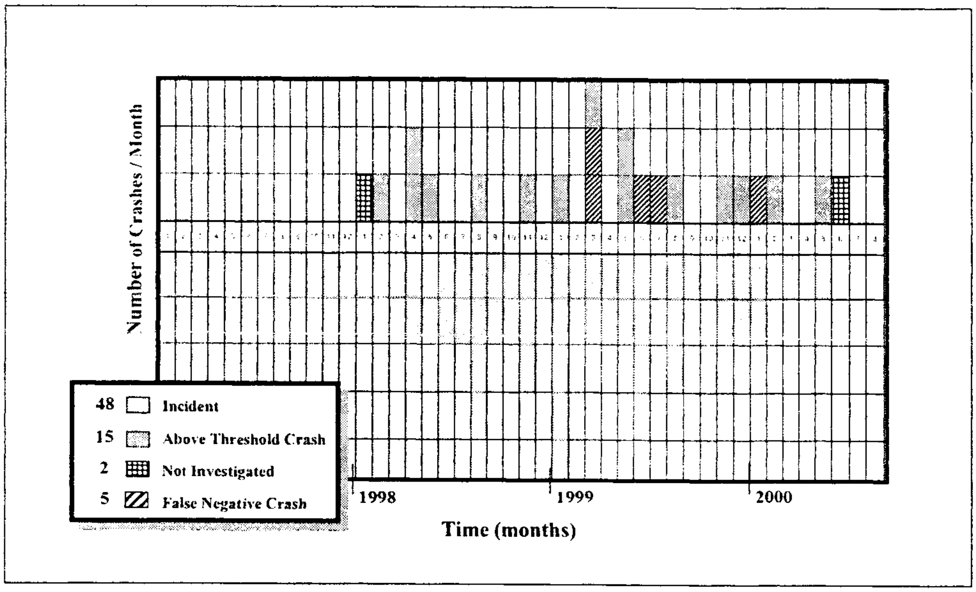

Figure 3-6. Occurrence of ACN Incidents and Crashes

A total of 874 vehicles had ACN equipment installed for some period of time over the duration of the program. The total number of ACN vehicle days-in-the-field was 554,855, or 1,520 vehicle years-in-the-field, through the end of July 2000.

If the total number of crashes experienced in the ACN program is divided by the number of ACN vehicle years-in-the-field, a crash rate of 0 046 is obtained. If the number of above threshold crashes is divided by the years-in-the-field an above-threshold crash rate of 0.015 is obtained. In 1997 the national crash rate was 0.063 and the national crash rate with injury was 0 022 [NHTSA 1998]. The lower than average crash and injury rates experienced in the program may be a result of the fact that ACN participants were volunteers and concerned about crash safety and therefore were safer drivers than average or it may be that people who are able to pass the CellularOne (now Cingular) credit check are generally more responsible individuals and safer drivers In any case, the ACN crash rates are somewhat lower than the national crash rates.

In addition to the crashes and incidents shown in Figure 3-6, there have been thirty-one systems that have produced false positive alarms. These are vehicles that sent a crash notification when, in fact there was no crash False positive alarms have been due to accelerometer failures -- a failure of the accelerometer itself or an improperly installed accelerometer that indicated a high acceleration and when there was an unstable or intermittent power supply (e g , when participants attempted to "jump-start" their vehicles). The causes of these faulty accelerometer outputs and ways to prevent them have been identified. False positive alarms are discussed in more detail in Section 3 4 along with false negative crashes.

3.3.2 CET Crashes

Figure 3-7 shows the temporal distribution of CET crashes since the beginning of the ACN FOT It graphically shows crashes in the following categories:

- Crashes – Crashes that were above the threshold for initiating the timer. The CET crash threshold was approximately 12 kph in any direction.
- Incidents – Crashes that were below the crash threshold (e g., fender benders) for initiating the timer.
- Not Investigated – Crashes that occurred outside the CET test area or were not investigated for some other reason, i e., the CET was missing or notification was received too late to calculate the crash time
- False negatives – Crashes that were above threshold (as determined by post crash reconstruction) but for which the CET was not functioning and did not initiate timing

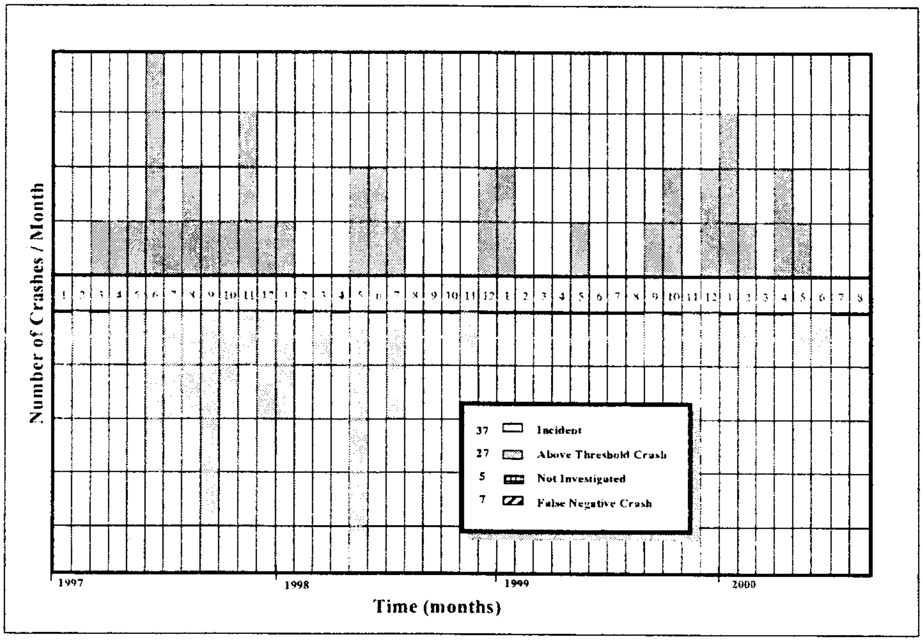

Figure 3-7. Occurrence of CET Incidents and Crashes

During the three and a half years during which CETs were in the field, a total of thirty-nine above-threshold crashes were reported. Of these crashes, seven did not have a functioning CET onboard and the time of the crash could not be calculated, five were not investigated because notice of the crash was not received until after the CET had reset (i.e., more than three weeks) An additional thirty-seven crashes that were below the CET crash threshold were reported. A total of 3,044 CETs were installed in vehicles over the duration of the ACN program A total of 3,254,159 days-in-the-field, or 8,916 years-in-the-field, were accumulated for the CETs through July 2000. If the total number of crashes experienced in the CET program is divided by the number of CET vehicle years-in-the-field, a crash rate of 0 0085 is obtained. If the number of above threshold crashes is divided by the years-in-the-field, an above-threshold crash rate of 0.0038 is obtained. As mentioned above, in 1997 the national crash rate was 0.063 and the national crash rate with injury was 0.022 [NHTSA 1998]. The ACN crash rate was 0 046 and the above threshold crash rate was 0 015. The CET crash rates were far below the national rates and far below the ACN crash rates.

Original estimates of crash frequency had indicated that with 3,000 CETs in the field, approximately ninety crashes per year could be expected Our best explanation for the difference between actual and expected crash rates was that the drivers and the police were not reporting CET crashes to Veridian Engineering when they occurred. In order to verify this assumption, a list of the license plate numbers for every vehicle enrolled in the CET program was sent to the State of New York Department of Motor Vehicles where the list was cross-referenced with the license plate numbers of every crash that had occurred in New York State during the program period The results supported the explanation: 146 CET vehicles had been involved in a crash in New York State during the program period. Of these 146 crashes, 91 involved personal injury and 55 involved property damage only. Because we did not receive the expected notifications, the CET program was unable to collect data to reconstruct emergency response timelines for 91 injury-producing cases.

In an attempt to correct this problem, a pro-active crash identification policy was implemented. Under this policy, Veridian personnel contacted all local, county and state police jurisdictions in Western New York at least once every two weeks and collected a list of the license plate numbers of all vehicles involved in crashes. This contact was by telephone or fax, or in some cases a personal visit was made to the police station: whatever methodology best suited each local police department. Veridian personnel actively created a list of license plate numbers for all crashes, which was cross-referenced with the license plate numbers of CET (and ACN) program participants. In this way all CET (and ACN) crashes that occurred in the program test area were identified. The participants and the local police were then contacted by telephone and if there was an emergency response of any kind, the crash was investigated and a response timeline was constructed Because the CET resets the internal crash timer three weeks after a crash has occurred, this process had to take place within that three week time period. This active and aggressive crash identification process was pursued for approximately four months.

After four months, only four above threshold and four below threshold CET crashes were identified (see Figure 3-7). There were several potential reasons for the low crash rates that were observed First, the City of Buffalo Police Department did not fully cooperate with the crash data collection effort (they wished to be paid for police reports), which meant many crashes were not being identified. It should be noted that the City of Buffalo would have accounted for approximately 40% of the total number of crashes in Erie County, New York. However, the identified total number of crashes is far too small even considering that the City was not included It can only be assumed that many CET vehicles had been removed from the fleet in Western New York over the three and a half year duration of the program or that CET vehicles were not involved in crashes for some reason. It should be noted that the CET participant recruitment methodology was to utilize civic organizations in rural and suburban areas to install CETs into vehicles, which may also have been a factor in this failure to identify CET crashes. The active collection of police reports and license plate numbers was terminated after four months due to the expense of the program and the failure to produce the desired result.

3.4 ACN False Positive Alarms and False Negative Crashes

3.4.1 False Positive Alarms

False alarms are produced by an accelerometer (or accelerometers) indicating an above threshold crash when one did not occur. One cause of these faulty accelerometer outputs was hardware related. When an accelerometer is not properly mounted parallel to the board surface, it can contact the board causing a ground short which creates an acceleration spike. The addition of a spacer between the accelerometers and the board that would prevent this contact is a possible design solution. Thirteen of the thirty-one units that caused false alarms did so as a result of ground shorts due to poor accelerometer installations. Another cause of false alarms is unstable or intermittent power supplied to the in-vehicle system. Examples of unstable power that were experienced include: jump-starting a vehicle's dead battery, intermittent contact between a loose wire or cable and the vehicle's engine or body; ignition shut-off that does not cause the vehicle's voltage to drop immediately to zero but instead drops slowly and confuses the IVM; and one case in which the in-vehicle system became submerged in water when the vehicle's windows were left open during a rain storm.

The false alarms caused by grounding of accelerometers were eliminated through a software upgrade (version 1 3). The upgraded IVM software recognized unrealistic spikes in acceleration and did not report a crash For the case where the vehicle's voltage is low and unstable after the ignition is switched off, a relay was installed that immediately cut the voltage to the in-vehicle system when the vehicle was turned off The false alarm rate was reduced significantly as the number of ACN vehicles in the field with the new software increased. It was not possible to upgrade every system in the field. Software upgrades were implemented in those units that generated a false alarm and in any other units that were conveniently available. A notice offering the software upgrade to participants was included in the ACN newsletter (see Appendix A) and many participants brought their vehicles to Veridian Engineering to receive the upgrade. The status of the software upgrade installations is given in Section 3 6

3.4.2 False Negative Crashes

There were five false negative ACN crashes. False negative crashes are defined as those crashes that should have been recognized by the ACN in-vehicle module and for which a crash call should have been made to the Erie County Sheriff. In these false negative cases, the system did not operate properly and notification of the crash was not received at the Sheriff's dispatch center. The five false negative cases were. No 1346 on March 3, 1999; No. 1289 on March 22, 1999; No 1632 on June 18, 1999; No. 1323 on July 4, 1999, and No 1408 on January 13, 2000 These false negatives fall into two categories. (1) the crash was detected but the call was not received; and (2) the crash was not detected

Four of the 5 false negatives fall into the first category, crash detected by the in-vehicle ACN system, but call not received. The reasons for this were: (1) poor cellular coverage so that the call could not go through; (2) ACN modem at the Sheriff's Office was inadvertently disconnected; (3) ACN back-up battery failure when vehicle power was lost due to the crash (crash detected but call could not be made); and (4) equipment was damaged during the crash (crash detected but call could not be made)

One false negative was in the not detected category Although this crash was carefully analyzed, the cause of this failure was not determined.

During the program a great deal of attention was devoted to understanding the reasons for the false negative crashes. The causes for four of the five false negative crashes that occurred were determined (as described above) and steps were taken, when possible, to avoid additional occurrences of these problems. The other case, No 1346, is not understood and will likely remain a mystery. Each of these cases is discussed below.

ACN False Negative Crash No. 1346

This ACN crash occurred in the winter and resulted from one, or both, of the involved vehicles crossing the center line and impacting each other on their left front side structures in an angled frontal-side impact. The ACN failed to call the dispatch center and the husband of the injured driver/occupant of the ACN vehicle informed Veridian about the crash several days after the crash. Veridian personnel retrieved the ACN hardware from the crashed vehicle. The ACN was packed in heavy snow because the roof had been removed to extract the injured driver and it had snowed during the time following the crash. The retrieved ACN was not working when it was tested in the laboratory. After drying out the hardware in the laboratory, it began working again, however, there were no data in the permanent ACN memory. Since the ACN unit was extremely wet when retrieved, it was not considered surprising that the memory was blank It is not known if the ACN recognized the crash and recorded the crash data, which was subsequently erased due to the wet conditions and short circuiting of the power, or if the data was never recorded. The crash was clearly of sufficient severity that it should have been recognized by the ACN The cellular coverage at the site of the crash was acceptable and a cellular call should have been possible. The crash intrusion did damage the fuse panel and may have interfered with ACN power; however, it is felt that by the time the fuse box was damaged the crash recognition should have been in progress and the back-up battery should have provided power. At this time, no explanation is available for this false negative case.

ACN False Negative Crash No. 1289

This false negative ACN crash occurred on a foggy, snowy evening on a rural expressway during the rush hour commute The ACN vehicle driver failed to see the vehicle in front of him stop and impacted that vehicle in the rear The ACN vehicle was then struck in the rear twice more as vehicles behind the ACN vehicle also failed to stop. A total of sixteen vehicles were involved in this chain reaction crash. The ACN system's back-up battery was found to have corroded terminals and the battery was not providing power to the system. At the time of the crash, the ACN vehicle was using lights, heater, defroster and rear window defroster. After the crash the vehicle was turned off and it is felt that the power provided by the vehicle battery, under heavy load from the accessories being used, dropped to less than 11 volts. Since the back-up battery was not available, there was insufficient voltage to place a cellular call. The ACN unit recognized the crash and the acceleration time history was stored in memory Modified software was subsequently incorporated into the ACN transceiver that will allow calls to be made with voltage as low as 9 volts. It was felt that this design modification would eliminate this type of false negative problem in the future.

ACN False Negative Crash No. 1632

This false negative ACN crash occurred in a rural village in a remote southeast area of Erie County, New York. The ACN unit recognized the crash and crash data was stored in the permanent memory. The cellular coverage at the location of the crash was extremely poor - almost not existent - and the cellular call to the Sheriff's dispatch center could not be completed. This type of false negative is unavoidable but will become less likely as cellular coverage improves.

ACN False Negative Crash No. 1323

This ACN false negative crash occurred when the ACN vehicle was impacted in the right side at high speed by another vehicle. The delta V of the crash was approximately 50 kph and intrusion into the ACN vehicle was massive (approximately 100 cm) The ACN hardware was impacted by the intruding side structure of the vehicle and the power line to the transceiver was short-circuited The ACN recognized the crash and the data was stored in permanent memory and was later retrieved for analysis. This type of ACN false negative is difficult to avoid and can only be prevented by locating the ACN in areas that are not likely to be impacted and by "ruggedizing" the hardware to withstand severe crashes.

ACN False Negative Crash No. 1408

This ACN false negative crash when the ACN vehicle lost control and ran off of the road in snowy and icy conditions. The vehicle entered a ditch on the left side of the road and impacted the side of the ditch with the driver's side of the vehicle. The IVM memory recorded a nine o'clock impact with a change of velocity of 19 kph, which was sufficient to trigger an emergency message call For an unknown reason the modem cable for the ACN system server at the Sheriff's office was disconnected and the call could not be received. Since the server could not receive the call, it could not route the call to the Sheriff's dispatcher or to the MERS dispatcher. Subsequent inspection of the system discovered the disconnected cable Undisturbed dust on the cable, the cable connector and the server back plane indicated that no person had disconnected the cable and that it was probably accidental. After connecting the modem cable the system began working normally.

3.5 ACN Reliability

Of the twenty above-threshold ACN crashes that occurred in this field operational test, nineteen were correctly recognized, correctly processed, and an attempt was made to call the Erie County Sheriff's Dispatch Center. Although only fifteen of those calls were received at the dispatch center, the in-vehicle module (IVM) performed its design function correctly nineteen out of twenty times The five calls that were not received, the false negative cases, were discussed previously in Section 3.4.2 Four of the five false negative cases had acceleration data in memory and attempted to call the Dispatch Center. ACN 1346 is the false negative case for which there is no explanation as to why the system did not function and it is not known whether the system attempted to call or not. Of the forty-nine below-threshold ACN crashes, the ACN recognized that the crash was not sufficiently severe to call the Dispatch Center and did not call. The IVM was reliable in the sense that it recognized crashes correctly, processed the data correctly, and attempted to place a call to the Dispatch Center when appropriate. The IVM reliability is summarized in Table 3-4.

Table 3-4. ACN In-Vehicle Module Reliability

	Above Threshold Crashes	Below Threshold Crashes
Crash Detected	19	0
Crash Not Detected	1 (?)	49

The ACN system includes the IVM and the Gateway call receiving stations at the Erie County Sheriff's Dispatch Center and at the Mobile Emergency Radio System (MERS) at the Erie County Medical Center. The reliability of the total ACN system includes the entire crash notification process. recognizing a crash, processing the data correctly, and completing an emergency call to the Dispatch Centers. The ACN system failed to complete an emergency call five times as discussed previously in Section 3.2.4 In addition to these false negative cases, there were thirty-one units that called the Dispatch Center when there was no reason to do so, i.e., false positive calls. As discussed previously these calls were due to ground faults and voltage control problems These thirty-one false positive, or false alarm, units were a small portion of the 874 units that were in the field over the duration of the ACN Field Operational Test and they should not be compared, in quantity, to the relatively small number of ACN crashes. ACN system reliability is summarized in Table 3-5, below.

Table 3-5. ACN System Reliability

	Above Threshold Crashes	Below Threshold Crashes	Non-Crash Events
Call Received	15	0	31*
Call Not Received	5	49	N/A

** 31 out of 874 Units in the field. These hardware problems would be eliminated in production version.*

3.6 System Maintenance and Upgrades

This section summarizes the ACN System maintenance activities that were performed throughout the operational test The largest part of this effort was maintaining the in-vehicle equipment with the dispatcher equipment requiring only occasional maintenance. This section summarizes the maintenance activities

The maintenance of the in-vehicle ACN units was very labor intensive. It involved:

- Responding to questions and requests for maintenance from participants (this frequently included questions about cellular phone bills and other issues unrelated to ACN equipment operation).
- Identifying units that were not performing their scheduled self-test calls and following up to diagnose the problem and initiate repair actions as needed.
- Scheduling and confirming appointments with participants for field service.
- Traveling to participants' residences to repair in-vehicle equipment. This included inspection of equipment for loose wires and obvious damage, working with the participants to understand all symptoms, and replacing equipment components as needed. This sometimes involved removal and replacement of the IVM, transceiver, handset, wiring, or back-up battery.
- Troubleshooting removed equipment to determine the cause of problems that were not readily identified in the field.
- Completing maintenance paperwork for logging and tracking maintenance status and updating the maintenance database

During the program, 115 of the problems were reported for maintenance. Service was performed on all but two of the 115 ACN units. The other two units were reported to produce false alarms that were caused by jump-starting the vehicle. These units were not permanently affected and required no additional maintenance In almost all cases a Veridian ACN technician performed the service. Ninety-two components were replaced during service. Many of the components that were removed did not have a confirmed defect but were replaced for expediency, allowing the removed unit to be inspected at a later time. The 113 ACN units that were serviced are categorized by maintenance area in Table 3-6 A description of each category follows.

Table 3-6. Maintenance Categories

Maintenance Area	Units Serviced
Accelerometers	16
Back-up Battery	1
Flash Memory	1
GPS	8
Handset	5
IVM	32
Power Cable	7
RCU	7
Transceiver	15
Other	23

The following section describes ACN system problem areas and the criteria used to classify problems as either defective or failed components or as installation and environmental problems.

Accelerometers

Accelerometer errors were sometimes reported via self-test call status (Error 01(X), 02(Y), 04(Z)). Most accelerometer errors resulted in the erroneous initiation of an emergency call to the Sheriff's office resulting in a false alarm (false positive).

Backup battery

Most battery problems resulted from harsh environments and were discovered during physical examination of an ACN system. Corroded terminals caused by inadequate ventilation or pooling of moisture were found to prevent the battery from charging correctly. Occasionally the chemicals within the battery had begun to sulfate, an operational defect, which renders the battery dead and irreparable.

Flash memory

Flash memory failures were reported in self-test calls If the memory failed, the self-test would report an "Error020" or the self-test call would be overdue.

GPS

Most participants did not check the handset for a GPS icon when they used the vehicle or the telephone; therefore, most reports of GPS system problems were generated by self-test calls. A self-test call would either report a GPS error or the self-test call would be late because the ACN system uses GPS to regulate its internal clock. A few verbal reports were received from participants who noticed that the handset was displaying "Error08."

Handset

The handset was used by the driver for making calls; therefore, all handset problems were easily detected and reported by the participant. Most handset problems were due to a malfunction or abuse. Common handset malfunctions included faint or absent start-up tones, scratchy sound quality from the speaker, absence (failure) of the hands-free operation feature, loss of backlighting on the display, or the loss of the LCD display. There were also a few problems, such as pinched cables, resulting from incorrect installation

Power cable

Malfunctions of the power cable would cause the power to the IVM to fail completely or to become intermittent. These problems were most commonly reported by the participant, but were also found by reviewing the self-test call log (the system might call in late or not at all). Power cables could be pinched and damaged during installation or the main power wires to the vehicle could be incorrectly installed. Power cable problems, such as a pinched cable or a broken thumbscrew on the IVM D-connector, could also be a result of accidental damage or abuse

Reference Correction Unit (RCU)

The RCU was designed to electronically account for the IVM alignment within the vehicle. During the ACN installation process it was used to generate a coordinate reference matrix that was downloaded into the IVM. This allowed the measured accelerations to be correctly translated into the principal axes of the vehicle. The in-vehicle module would report an "Error 040" if the transformation matrix generated by the RCU was absent or corrupted. All reports of this error were via self-test call because participants were unaware of the existence of the transformation matrix.

Transceiver

Most transceiver problems were discovered from the biweekly self-test call made by each IVM to Veridian Engineering or from participant telephone calls. Faulty transceivers could cause self-test calls to be intermittent and overdue or could be reported as errors reported in the self-test call data. A faulty but operational transceiver could report an internal error (error 10) at the conclusion of a self-test call. On occasion, participants called Veridian Engineering to report dropped cellular telephone calls indicating a transceiver problem. Almost all transceiver problems were caused by internal transceiver malfunctions. Only a small number of transceiver problems were found to be due to an external problem such as disconnected power supplies.

Other

Other miscellaneous problems occurred and are briefly listed below.

- Phone stays on after key is turned off
- Erratic IVM operation due to improper wiring during installation
- Antenna cable was damaged during installation
- Handset cable was damaged during installation resulting in erratic handset operation
- Erratic IVM operation due to a poor ground connection
- The system would not call in because it was removed without informing Veridian
- Antenna was not replaced when a broken window was replaced
- IVM would not boot due to internal hardware or software problems

In addition to conducting maintenance on ACN units in response to problem indications, software upgrades were being performed on all IVMs. Table 3-7 shows all IVM software releases with a description of the changes implemented in each.

Table 3-7. IVM Software Releases

Software Version	Description
1.0	• Initial release
1.1	• This upgrade was required due to a change in IVM hardware (new modem chip) The software was not applied to correct bugs and was only applied to units in stock.
1.2	• This upgrade fixed a mathematical error related to the RCU transformation matrix; the error could have potentially effected principal direction of force (PDOF) calculations. • This upgrade corrected a false indication of a GPS error. The error was appearing on the display of some participant's handsets as "SYSTEM ERROR 08" even though there was no actual error. • This software upgrade also limited the length of time a cellular self-test call could remain connected to ten minutes. This was done in response to some large cellular charges incurred by participants whose units made self-test calls while in roam mode. This was a temporary solution until the problem was further researched.
1.3	• This upgrade prevented cellular self-test calls while in roam mode. The ten-minute call time limit allowed by version 1 2 was still enabling participants to incur expensive cellular bills. The problem was identified as an incompatibility with older equipment used by some cellular providers outside of the local area. The cellular phones were not receiving the signal to disconnect. This caused phones to remain connected to these cellular sites and accrue roaming charges This was only a problem with data calls (i e., self-test calls), not voice calls • This upgrade also enhanced the reliability of receiving crash calls in areas with older cellular technology. • This upgraded software version recognized unrealistic accelerations and filtered these occurrences to prevent false alarm messages from being sent (See Section 3.4.1) • This upgrade made several enhancements to the handset's display making it more user-friendly and easier to read.

During the program, participants who required an IVM software upgrade or needed their equipment serviced were offered a $5 certificate for groceries at a local supermarket as incentive to bring their vehicle to Veridian for service. This saved about $25 in labor and expenses otherwise required for travel, and was viewed very positively by the participants.

4 Analysis and Evaluation

4.1 ACN Crashes: Reported and Reconstructed Data

Each ACN crash was fully investigated by Veridian Crash Investigators. The crash was reconstructed to develop an independent measure of the crash characteristics (i.e., Principal Direction of Force (PDOF), delta Velocity, Final Rest Position and Rollover) and location accuracy (i.e., Latitude/Longitude and Heading). Emergency notification and response timelines were also constructed and documented. Complete sets of descriptive data for all above threshold ACN and CET crashes are presented in Appendix B.

In addition to the collection of this data, a comparison between the ACN-derived crash data and the reconstructed crash data is presented in Table 4-1.

As can be seen in Table 4-1, there was generally good agreement between the ACN derived crash characteristics and those determined independently by Veridian Crash Investigators. A more complete discussion of each of the crashes is presented in Section 4.3.

Table 4-1. Comparison of ACN Reported Crash Parameters with those Derived by the Crash Investigator

ACN ID #	Date	Time	Location	Crash Description		ACN	Reconstruction
1129	1/3/98	7:55p	Urban area (outside of test area) in a 4-way intersection (ACN failed to call-in)	ACN vehicle impacted the principal other vehicle in the left side at 90 degrees	**PDOF**	12 o'clock	1 o'clock
					delta V	19.9 kph	<24 kph
					Rollover	No	No
					Final Rest	N/A	Normal
					Latitude	Unknown	Unknown
					Longitude	Unknown	Unknown
					Heading	Unknown	Unknown
1104	2/18/98	1:49p	Urban area in a four-way intersection	ACN vehicle turned into path of an oncoming vehicle	**PDOF**	2 o'clock	2 o'clock
					delta V	22.5 kph	17.2 kph
					Rollover	No	No
					Final Rest	N/A	Normal
					Latitude	42 90566 deg	42.90472 deg
					Longitude	78.86873 deg	78.86855 deg
					Heading	194 deg.	120 deg.
1239	4/4/98	3:21a	Rural village area on a curving road	ACN vehicle ran off the road to the right, hit a utility pole guy wire and tipped over onto the right side	**PDOF**	3 o'clock	3 o'clock
					delta V	12 9 kph	9-15 kph
					Rollover	No	Yes
					Final Rest	N/A	Right Side
					Latitude	42.79156 deg	42.79165 deg
					Longitude	78.55404 deg.	78.55453 deg
					Heading	200 deg.	200 deg.
1046	4/15/98	5:41a	Rural unpopulated area on a two-lane road	ACN vehicle ran off of road to the right and hit a tree stump	**PDOF**	12 o'clock	12 o'clock
					delta V	30.6 kph	26 kph
					Rollover	No	No
					Final Rest	N/A	Normal
					Latitude	42.69661 deg.	42.69538 deg
					Longitude	78.62294 deg.	78.62345 deg
					Heading	172 deg.	160 deg.

Table 4-1. Comparison of ACN Reported Crash Parameters with those Derived by the Crash Investigator (continued)

ACN ID #	Date	Time	Location	Crash Description		ACN	Reconstruction
1109	5/8/98	7:48a	Urban area at an intersection	ACN vehicle was waiting at a red light and was impacted from behind and pushed into the vehicle in front	**PDOF**	6 o'clock	6 o'clock/12 o'clock
					delta V	29 0 kph	30 1 kph / 12 9-16 1 kph
					Rollover	No	No / No
					Final Rest	N/A	Normal
					Latitude	42 87411 deg	42 87372 deg
					Longitude	78 84379 deg	78 84345 deg
					Heading	not moving	not moving
1254	8/31/98	6:47p	Suburban area on a residential street	ACN vehicle turned left into path of an oncoming vehicle	**PDOF**	12 o'clock	11-12 o'clock
					delta V	16 1 kph	18 6 kph
					Rollover	No	No
					Final Rest	N/A	Normal
					Latitude	42 71766 deg	42 71755 deg
					Longitude	78 82840 deg	78 82845 deg
					Heading	99 deg.	East
1463	11/15/98	3:19p	Urban area (outside of test area) at a four-way intersection	ACN vehicle was struck in the right front by the principal other vehicle	**PDOF**	3 o'clock	2 o'clock
					delta V	22 5 kph	29 3 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42 78604 deg	42 78639 deg
					Longitude	78 81125 deg	78 81104 deg
					Heading	314 deg.	North West
1094	1/31/99	4:40p	Suburban business area at a three-way intersection	ACN vehicle was struck in the left front and subsequently struck an icy snow bank with the right rear wheel	**PDOF**	2 o'clock	11 o'clock/3 o'clock
					delta V	25 8 kph	16-19 kph/8-11 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42 86777 deg	42 86800 deg
					Longitude	78 74248 deg	78 74242 deg
					Heading	92 deg.	91 deg.
1343	3/4/99	9:06p	Rural area on a two-lane road	ACN vehicle skidded on ice and hit a utility pole with the front structure	**PDOF**	12 o'clock	11 o'clock
					delta V	19 0 kph	21 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	43 03348 deg	43 03451 deg
					Longitude	78 47298 deg	78 47249 deg
					Heading	51 deg.	54 deg.
1478	5/8/99	5:45p	Suburban area on a four lane road	ACN vehicle was struck in the left front by a vehicle that crossed the center line	**PDOF**	11 o'clock	11 o'clock
					delta V	37 3 kph	32 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42 77601 deg	42 77677 deg
					Longitude	78 82337 deg	78 82370 deg
					Heading	1 deg.	North

Table 4-1. Comparison of ACN Reported Crash Parameters with those Derived by the Crash Investigator (continued)

ACN ID #	Date	Time	Location	Crash Description		ACN	Reconstruction
1268	5/24/99	11:24a	Suburban area with businesses at a four-way, multiple lane intersection	ACN vehicle was struck in the right front by a vehicle that went through a red light	**PDOF**	2 o'clock	2 o'clock
					delta V	27 kph	27 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42.78604 deg.	42.78639 deg.
					Longitude	78.81125 deg.	78.81104 deg.
					Heading	95 deg.	East
1707	8/9/99	9:43a	Suburban commercial 3 way intersection	ACN vehicle struck the other vehicle's left front when the other vehicle pulled onto roadway	**PDOF**	12 o'clock	12 o'clock
					delta V	22.5 kph	19-22 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42.95094 deg.	42.95043 deg.
					Longitude	78.69574 deg.	78.69673 deg.
					Heading	12 deg.	North
1729	11/23/99	6:19a	Rural two lane road	Deer struck ACN vehicle on the left side causing the driver to lose control and run off of road to the left side into a drainage ditch	**PDOF**	9 o'clock	9 o'clock
					delta V	21 kph	NA (sideswipe)
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42.80846 deg.	
					Longitude	78.53596 deg.	
					Heading	3 deg.	North
1205	12/27/99	5:11 p	Suburban commercial four lane roadway	A vehicle was making a left turn across traffic into a parking lot. The driver's foot slipped off of the brake pedal and the vehicle moved into the path of the ACN vehicle. The front of the ACN vehicle struck the right front corner of the turning vehicle.	**PDOF**	11 o'clock	11 o'clock
					delta V	12 kph	13 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42.88700	
					Longitude	78.75465	
					Heading	181 deg	South
1760	2/5/00	9:12 p	Rural residential two lane roadway	The ACN vehicle was following another vehicle on a slippery snow covered roadway. The other vehicle slowed down and the ACN vehicle struck it from behind.	**PDOF**	12 o'clock	12 o'clock
					delta V	23 kph	15 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42.78286	
					Longitude	78.64684	
					Heading	335 deg.	North
1302	5/15/00	1.53 p	Suburban commercial five lane roadway	The driver of the ACN vehicle failed to recognize that traffic had stopped and impacted the rear of a vehicle.	**PDOF**	12 o'clock	12 o'clock
					delta V	42 kph	> 23 kph
					Rollover	No	No
					Final Rest	Normal	Normal
					Latitude	42.75664	
					Longitude	78.85997	
					Heading	151 deg.	South-southeast

4.2 ACN Crash Location and Vehicle Heading Accuracy

In addition to the accuracy of the ACN reported crash PDOF and delta V, the accuracy of the reported location of the crash was assessed. The ACN obtains the crash location latitude and longitude from the Global Positioning System (GPS). The error in the GPS reported position varies with the number of GPS satellites available at the time, and includes error that was intentionally included by the United States government to prevent GPS from being used for military targeting functions. This latter intentional error is called Selective Availability. (Note: at the very end of the program, the government removed selective availability)

The error in the location of the crash was determined by comparing the location transmitted by the ACN that was involved in the crash with the location obtained from a Differential GPS system positioned at the crash site at a later time. Differential GPS eliminates the error due to Selective Availability by comparing the location signal received from the GPS satellites with the position of a known location near the crash location. The error due to Selective Availability was quantified and subtracted from the standard GPS location signal. This differentially corrected GPS location was then compared to the ACN location and a vector subtraction calculation was performed to obtain the error in crash location in meters on the surface of the earth.

Table 4-2 shows the error calculated using the Differential GPS location. It was generally accepted that standard (non-Differential) GPS location is accurate to within 100 meters, 67% of the time (one sigma). It can be seen that in seven out of the eleven ACN crashes, or 64% of the crashes, the error is less than 100 meters. The ACN system location accuracy was within expected standard GPS accuracy.

Table 4-2. ACN Crash Location Accuracy

ACN ID #	Location Error (meters)
1104	118.0
1239	41.2
1046	142.9
1109	54.2
1254	12.9
1463	21.5
1094	31.5
1343	123.8
1478	87.9
1268	13.6
1707	113.5
1729	40.6
1205	11.2
1760	73.8
1302	52.0

The error shown in Table 4-2 is a measure of the absolute accuracy of the ACN reported crash latitude and longitude Very few public safety agencies use GPS equipment to locate the scene to which they have been sent. The ability to travel safely and quickly to a crash location is more important to the EMS and police responders than the absolute error in the reported crash location. Key information of importance to emergency response agencies includes: the road the vehicle is on, the direction the vehicle was traveling immediately prior to the crash, and the position of the crashed vehicle with respect to the road. Other factors that may affect response time are the quality of the crash site location description that the dispatcher receives, the quality of the crash site description that the dispatcher gives to the EMS and police responders, and the ability of the responders to choose a time-efficient travel route In some of the cases of large location error shown in Table 3-2, the crash was located very efficiently. For example, case #1343 occurred in a rural area with no trees, whereas, in case #1046 the vehicle was off of the road and out of sight. In the later case an accurate location would have been very helpful in finding this crash. It was felt that the map display of the crash location that the ACN system provides is a valuable aid in efficiently locating and reporting the crash site. The heading direction graphically shown on the map also aids the dispatcher in determining the lane of travel for limited access roads. When the map is faxed to EMS responders or to the local police it was found to be of great assistance by reducing confusion due to ineffective verbal communication of a crash location. The ability to fax the map and vehicle description is a tool provided to the dispatchers by the ACN system. The value of the map visual aid is difficult to measure in an objective manner. The error in location of crash sites listed in Table 4-2 is only one of the factors associated with locating a crash site.

The ACN in-vehicle module (IVM) obtains heading information from the GPS satellites. Heading is actually the direction of travel of the IVM between GPS satellite location calculations. In this report the term heading should be considered to be the direction of vehicle travel for both the ACN reported and displayed information and for the crash reconstruction.

4.3 Assessment of Agreement between ACN Reported Crash Parameters and Reconstruction

4.3.1 Case-By-Case Comparisons

ACN Crash No. 1129

This crash occurred early in the program in Chicago, Illinois and the ACN system did not report the crash because the proper long distance telephone coverage was not in effect. This problem was corrected to ensure that any subsequent out of area crashes would be properly reported. While the call was not successfully completed, the ACN did correctly sense the crash and the in-vehicle module retrieved and the crash data downloaded. The reconstruction data shown in Table 4-1 was based on photographs of the crashed ACN vehicle and an interview with the driver. The agreement between the ACN calculated crash characteristics and the reconstruction appeared reasonable, even though a detailed reconstruction could not be performed. The actual crash latitude and longitude and the vehicle heading immediately prior to the crash are not known.

ACN Crash No. 1104

The ACN vehicle turned left in front of an oncoming vehicle and was struck in the right front portion of the vehicle. The ACN system calculated a PDOF of 2 o'clock and delta V of 22.5 kph. The reconstruction also found a PDOF of 2 o'clock and delta V of 17.2 kph, providing reasonable agreement with the ACN derived crash data. The crash impact included the left front wheel and transaxle. These are very stiff structures that crush only small amounts making it difficult to estimate the delta V from the post-crash deformation. This may explain why the reconstruction delta V is less than the ACN delta V that is based on the actual vehicle crash accelerations. The error in location was approximately 104 meters (see Table 4-2) which is a substantial distance; however, at this large intersection location the EMS and police responders would most likely have found the crash easily. The discrepancy in heading is also rather large. The post-crash heading angle was taken using a magnetic compass from inside of a motor vehicle, which would have resulted in an erroneous reading of magnetic north due to the steel body. A heading of approximately 180°, taken from the map display, is probably more accurate as compared to the ACN heading of 194°.

ACN Crash No. 1239

This crash occurred in the very early morning in a rural village. The ACN vehicle ran off of the road to the right, drove over a ditch and a driveway, struck a utility pole guy wire with the vehicle left front bumper, rode up the wire and tipped over onto the vehicle's right side. The ACN system recognized the impact of the vehicle with the ground as a right side impact with a PDOF of 3 o'clock and a delta V of 12.9 kph. The crash reconstruction yielded a PDOF of 3 o'clock and a delta V of between 9 and 15 kph. Because the vehicle rolled onto the right side it was difficult to use standard reconstruction techniques and a range of possible delta Vs was obtained. The ACN system (at the Sheriff's Office) did not properly display the fact that the vehicle's final rest position was on the right side (although the in-vehicle equipment did properly sense final rest position). This display problem was corrected following this crash. Other than this display problem, there was good agreement between the ACN and the manual crash reconstruction. The location error was 41 meters, which is quite good. The vehicle would have been easily visible from the road at that distance The heading angle as reported by the ACN system and as measured with a magnetic compass at the scene were the same at 200°

ACN Crash No. 1046

The ACN vehicle ran off of the road very early in the morning, hit a few small trees and then hit a larger tree stump, which resulted in the impact recognized by the ACN system. The ACN system calculated a PDOF of 12 o'clock and a delta V of 30.6 kph. The reconstruction found a PDOF of 12 o'clock and a delta V of 26 kph. This is excellent agreement. The location error was 140 meters which is substantial. This vehicle was well off of the road in a wooded area and may have been difficult to find if the driver were not conscious and able to alert the police and EMS responders. The heading angles agree very well at 172° and 160°.

ACN Crash No. 1109

This crash occurred during morning rush hour when the ACN vehicle was struck from behind while waiting at a red light. The ACN vehicle was pushed forward into the vehicle in front at which time the air bags deployed. The ACN recognized the first crash (from the rear) and also recorded data for the second crash. The ACN calculated the first crash to be at a PDOF of 6 o'clock and a delta V of 29.0 kph. The crash reconstruction yielded a PDOF of 6 o'clock and a delta V of 30.1 kph The second crash was calculated by the ACN to be at a PDOF of 12 o'clock and a delta V of 16.0 kph. These second crash characteristics were not sent to the dispatch center since the ACN system only reports the most severe of the crashes. The crash reconstruction found a PDOF of 12 o'clock and a delta V of 12.9-16 1 kph for this second crash The agreement for both of the crashes was quite good The location error for this crash was 42 meters and the vehicle would have been easily located at the intersection shown on the dispatch map display. The heading angle was reported by the ACN to be 0°. In this case the vehicle was not moving at the time of the crash and as a result there was no direction of travel and, therefore, no heading. The reconstruction also estimated that the vehicle was not moving at the time of the crash.

ACN Crash No. 1254

The ACN vehicle turned left in front of an oncoming vehicle and was struck in the front The PDOF was calculated by the ACN to be 12 o'clock and the delta V was found to be 16.1 kph. The crash reconstruction yielded a PDOF of 11 or 12 o'clock and a delta V of 18.6 kph. This is good agreement and the post-crash photographs indicate that the crash damage was left of center as would be the case in an 11 o'clock crash, which affected the reconstruction estimate of PDOF. The location error was 14 meters which is excellent. The heading angle reported by the ACN was 99° as compared to a heading of East (approximately 90°) obtained from reconstruction.

ACN Crash No. 1463

This crash occurred out of the test area in Rochester, New York. The ACN system made a call to the Erie County Sheriff's Office dispatch center and the dispatcher was able to call the Rochester police and verify that the proper authorities were handling the crash The ACN vehicle was struck in the right front in a four-way intersection. The ACN calculated a PDOF of 3 o'clock and a delta V of 22.5 kph. The crash reconstruction found a PDOF of 3 o'clock and a delta V of 29.3 kph. The location error was 24 meters, which is excellent agreement. The ACN reported heading was 314° as compared to a reconstruction estimate of North West (approximately 315°), which is also excellent agreement.

ACN Crash No. 1094

This ACN crash was interesting and a thorough understanding of the crash events was only possible through analysis of the data collected by the ACN unit. The ACN vehicle was struck in the left front fender, in a sideswipe type of crash, by a vehicle turning left into the path of the ACN vehicle. The ACN vehicle swerved right as a result of this impact and struck an icy snow bank with the right rear wheel. The second impact with the snow bank was the more severe of the two impact events although there was very little visible damage to the vehicle The first sideswipe impact was not sufficiently severe to trigger the ACN. The second impact with the icy snow bank was above threshold and recognized by the ACN. The manual crash reconstruction was unable to calculate a delta V for the snow bank impact because there was no visible damage. For the second crash (the snow bank) the ACN calculated a PDOF of 2 o'clock and a delta V of 25 8 kph For the first crash (sideswipe) the ACN did not report crash characteristics (since this crash was below threshold) but the ACN recorded and stored data indicated a PDOF of 10 o'clock and a delta V of 15 4 kph. The reconstruction of the first impact found a PDOF of 11 o'clock and a delta V of 16 to 19 kph. There was good agreement between the ACN and the manual crash reconstruction for the first crash, but the second crash was only detected by the ACN System The location error for this crash was 30 meters, which is excellent. The heading angle reported by the ACN system was 92° as compared to a post-crash heading angle measurement of 91° obtained from a magnetic compass The heading agreement was also excellent

ACN Crash No. 1343

In this single vehicle crash the ACN vehicle skidded out of control on icy pavement and struck a utility pole with the front structure of the vehicle The ACN calculated a PDOF of 12 o'clock and a delta V of 19 kph The crash reconstruction found a PDOF of 11 o'clock and a delta V of 21 kph. The ACN system and the reconstruction agreed quite well. In this case the post-crash photographs support the 12 o'clock PDOF. The location error was 121 meters which is a large error. In this case the terrain was cleared farmland and the vehicle would be easily found even if it were not on the road; however, in a wooded area a vehicle located 121 meters off of the road might be difficult to locate. The ACN reported heading angle was 51° and the post-crash measurement with a magnetic compass was 54°, which is excellent agreement.

ACN Crash No. 1478

The ACN vehicle was struck in the left front structure by a vehicle that crossed the centerline It was determined that the driver of the non-ACN vehicle had suffered a heart attack causing him to lose control of his vehicle The ACN calculated an 11 o'clock PDOF and a delta V of 37.3 kph. The manual crash reconstruction found a PDOF of 11 o'clock and a delta V of 32 kph This is good agreement for a crash that included considerable sideswipe deformation, which makes reconstruction difficult. The location error was 92 meters. At this busy intersection, police or EMS responders would have easily located this vehicle The estimated reconstruction heading was North (approximately 0°) as compared to the ACN reported heading of 1°, which is excellent agreement

ACN Crash No. 1268

A vehicle entering a four-way intersection against the traffic control signal struck the ACN vehicle in the right front structure. The ACN calculated a PDOF of 2 o'clock and a delta V of 27 kph The manual crash reconstruction yielded a PDOF of 2 o'clock and a delta V of 27 kph. The agreement between the ACN system and the reconstruction was perfect. The location error was 51 meters, which was adequate to locate the crash vehicle The heading angle reported by the ACN system was 95° as compared to the post-crash estimate of heading of East (approximately 90°), which is excellent agreement.

ACN Crash No. 1707

The ACN vehicle struck another vehicle in the left front fender when that other vehicle pulled out into traffic at a three-way intersection The ACN calculated a PDOF of 12 o'clock and a delta V of 22.5 kph The crash reconstruction found a PDOF of 12 o'clock and a delta V of 27.0 kph This is good agreement The location error was 7 meters, which is excellent The post-crash estimated heading was North (approximately 0°) as compared to the ACN system reported heading of 12°, which is also acceptable agreement.

ACN Crash No. 1729

The ACN vehicle came over a slight rise and encountered a deer crossing the road from left to right. The deer struck the vehicle in the left side door The driver steered right onto the shoulder of the roadway in an unsuccessful effort to avoid the deer and then steered left to return to the roadway but over-compensated and ran off of the road to the left and into a drainage ditch. The vehicle struck it's left rear into the embankment and came to rest leaning left in the ditch. The ACN unit calculated a PDOF of 9 o'clock and a delta V of 20.8 kph The crash reconstruction found a PDOF of 9 o'clock but was not able to calculate an accurate delta V for this sideswipe type of impact. The location error was 40.6 meters, which is acceptable agreement. The heading angle reported by the ACN unit was 3 degrees, essentially due north, which is the same direction of travel as found in reconstruction. The agreement between the ACN reported crash characteristics and the reconstruction is excellent except for the delta V. The value of 20.8 kph reported by the ACN unit includes the change in velocity in the longitudinal direction as well as the lateral direction making it a much larger value than can be estimated from vehicle side structural damage.

ACN Crash No. 1205

The ACN vehicle was traveling south in the inside lane of a four lane suburban commercial roadway when a vehicle turning left across traffic crossed the center line and moved into the lane The front of the ACN vehicle struck the right front corner of the turning vehicle. The ACN unit calculated a PDOF of 11 o'clock and a delta V of 12.1 kph The crash reconstruction found a PDOF of 11 o'clock and a delta V of 13 kph, which is excellent agreement The location error for this crash was 11.2 meters, which is also excellent. The police were able to locate this crash very easily. The ACN reported heading was 181 degrees, essentially due south, and the roadway is oriented in a north-south direction. The agreement between ACN and reconstruction was excellent for this case.

ACN Crash No. 1760

The ACN vehicle was following another vehicle on a roadway that was partially covered with drifted The vehicle ahead of the ACN vehicle slowed in a snow covered area and the ACN vehicle struck it from behind. The ACN calculated a PDOF of 12 o'clock and a delta V of 23 kph. The crash reconstruction found a PDOF of 12 o'clock and a delta V of 15 kph. The location error for this crash was 74 meters. The ACN reported heading was 335 degrees, or north-northwest, as compared to the roadway direction of north. The discrepancy in delta V is thought to be due to the amount of snow on the road at the crash site. Although the snow was melted when the crash investigation took place, an interview with the ACN vehicle driver indicated that several inches of snow might have been drifted across the road at the time of the crash. This layer of snow acting on the vehicle tires might cause the vehicles to decelerate an additional 5 to 8 kph over the duration of the crash. This additional velocity change, not reflected in vehicle structural damage, may account for the difference between the ACN reported delta V and the crash reconstruction delta V. Further, a significant layer of drifted snow on the road would explain the sudden deceleration of the vehicle in front of the ACN vehicle and the subsequent crash.

ACN Crash No. 1302

In this complicated crash the driver of the ACN vehicle failed to recognize that traffic had stopped in the outside lane of the five lane suburban commercial roadway. The vehicle that was two vehicles in front of the ACN vehicle was making a right turn into a driveway and had stopped in the lane to allow another vehicle to exit the same driveway, turning right into the same traffic lane The vehicle behind this vehicle also stopped in the lane. The ACN vehicle struck the second vehicle in line and pushed it into the first vehicle in line. The ACN reported PDOF was 12 o'clock and the delta V was 42 kph. The crash reconstruction found a PDOF of 12 o'clock and a delta V of approximately 23 kph. The ACN reported heading was 151 degrees and the roadway was oriented south-southeast. The location error for this crash was 52 meters The discrepancy in delta V was attributed to shortcomings in the ability of the WINSMASH model to properly calculate delta V for a complicated three-vehicle crash, such as occurred in this case. In this crash the ACN vehicle strikes the vehicle in front of it and the two vehicles then proceed to strike a third vehicle in front of both. A significant portion of the kinetic energy of the ACN vehicle is absorbed in the middle and forward vehicles. WINSMASH only accounts for crush in two vehicles and, as a result, underestimates the velocity change

4.3.2 ACN Accuracy

A summary of the accuracy of the ACN system reporting of crash characteristics is provided in Table 4-3. Criteria were established at the beginning of the ACN program against which the various crash characteristics could be measured. For the fifteen fully reconstructed ACN cases accuracy is summarized by calculating the number of cases for which each quantity was accurately reported divided by the denominator of fifteen total cases.

It can be seen that the accuracy of ACN reported crash characteristics was generally quite good The differences between investigator estimates of delta V and ACN measurements of delta V were attributed to the inability of the crash investigator to reliably reconstruct sideswipe or multiple crash events It was felt that in these difficult reconstruction cases the ACN measured and reported delta V was probably more accurate than the reconstruction.

It can be seen in Table 4-3 that the reported location accuracy was only 73% for the ACN cases based on an allowable distance error of 100 meters. Most of the ACN crash reported locations included GPS Selective Availability error (Selective Availability as described earlier was removed from the GPS signal in May 2000) As a result of Selective Availability being included in the location position, several ACN crashes were reported at locations greater than 100 meters from the actual crash location. GPS now provides much more accurate location information.

A more realistic measure of location accuracy should include the ability of the responders to locate the crash promptly. The actual location error in meters on the surface of the earth is less important than the capability to find a crash without lengthy searching. With this in mind, a method of measuring the ease of locating the ACN crashes was developed based on a variety of location data such as the correct road name, the correct nearest intersection, the correct direction of travel, the nearest address as well as the distance of the reported crash location from the actual crash location Using this method, a point was given for each location attribute that was correct and a scale from 0 to 8 was established with 0 being difficult to locate and 8 being easy to locate This method is demonstrated in Figure

4-1. It can be seen that using this methodology all but one of the ACN crashes were reported with a location attribute of 5 or greater. This indicates that with one exception, all ACN crashes were could be readily located

Table 4-3. Summary of ACN Reporting Accuracy

Quantity	Criterion	Accurate
Delta V	(within 10 km/h)	87%
PDOF	(within 1 o'clock)	100%
Rollover	(yes/no)	93%
Final Rest	(yes/no)	100%
Location	(within 100 meters)	73%
Heading	(within 15 degrees)	100%

ACN ID	Correct Town	Correct Road	Correct Nearest Intersection	Correct Address	Correct Direction of Travel	Location Error <200 m	Location Error <100 m	Location Error <30 m	Total
1046	1	1	1	0	1	1	0	0	5
1094	1	1	0	0	1	1	1	0	5
1104	1	0	0	0	1	1	0	0	3
1109	1	1	1	1	1	1	1	0	7
1239	1	1	1	0	1	1	1	0	6
1254	1	1	1	1	1	1	1	1	8
1268	1	1	1	0	1	1	1	1	7
1343	1	1	1	0	1	1	0	0	5
1463	1	1	1	0	1	1	1	1	7
1478	1	1	1	0	1	1	1	0	6
1707	1	1	1	0	1	1	0	0	5
1729	1	1	1	0	1	1	1	0	6
1205	1	1	1	1	1	1	1	0	7
1760	1	1	1	1	1	1	1	1	8
1302	1	1	1	1	1	1	1	0	7

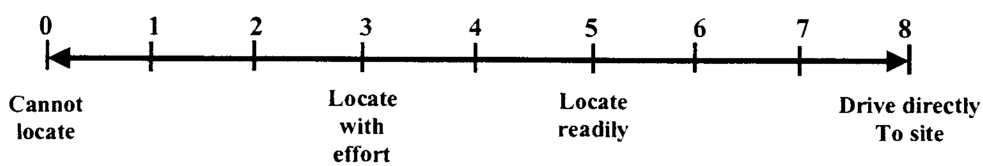

Figure 4-1. The Ease of Locating an ACN Crash

4.4 ACN Crash Response Time Analysis

An important goal of the ACN FOT was to measure the extent to which automatic crash notification can reduce emergency response time. To serve this goal the ACN field operational test included the CET program About three thousand CETs (crash event timers) were fielded to quantify the baseline notification times for non-ACN vehicles involved in crashes. CETs are timers that were activated by an inertial switch. When a crash occurred, the CET was started allowing post crash determination of exactly when the crash occurred.

The notification times for all ACN crashes and for all CET crashes are shown in the histogram of Figure 4-2. It is clear that the ACN system was able to notify the Erie County Sheriff of a crash in two minutes or less and usually in less than one minute. The non-ACN notification times range from one minute to as long as forty-six minutes. The average crash notification time in New York State, as reported from FARS, is approximately seven minutes (see Figure 4-2) It is clear that the ACN system reduced average notification times to less than two minutes.

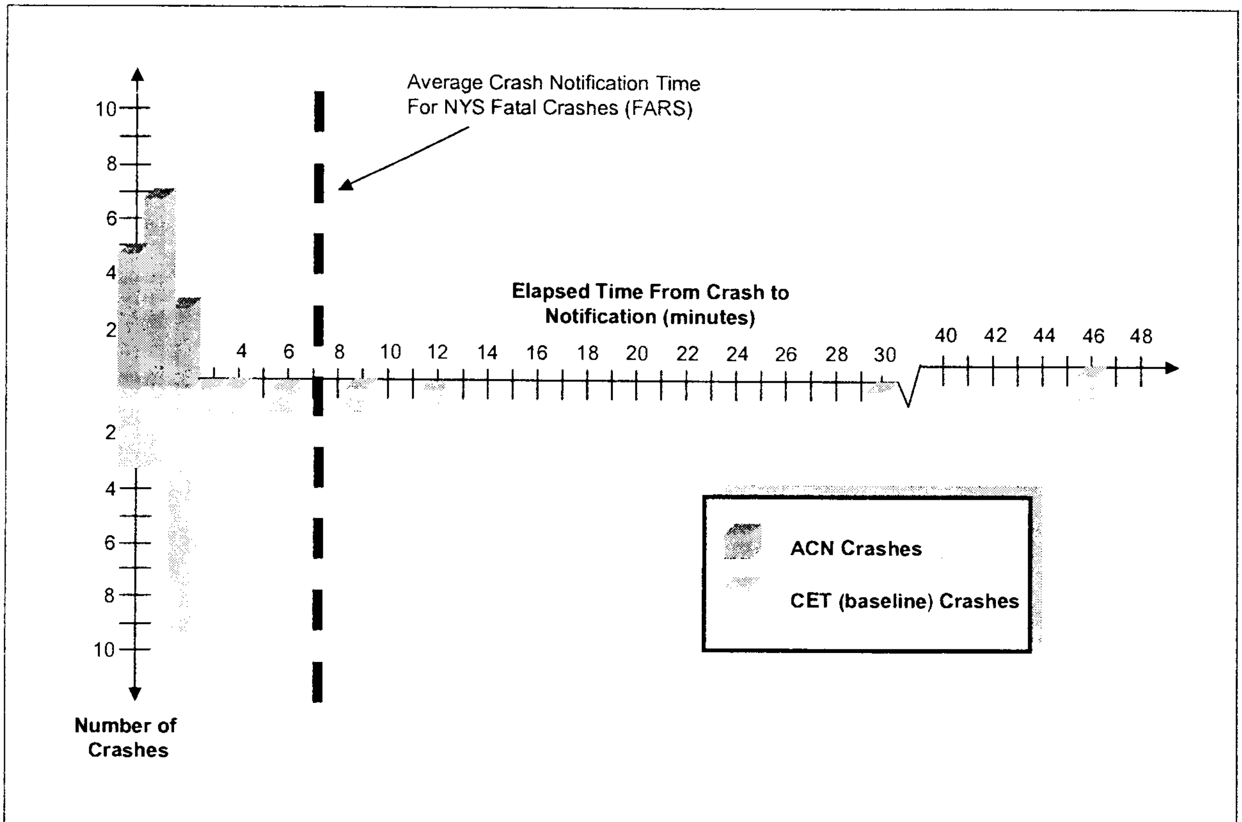

Figure 4-2. Histogram of ACN and CET Crash Notification Times

In addition to the ACN and CET crashes, a series of simulated crash calls were made to the Erie County Sheriff dispatchers throughout the ACN program These calls were made using a portable system that triggered a simulated crash call by manually pushing a button The portable system consisted of an IVM, installed in a suitcase, with a push-button that grounded an accelerometer to generate a high voltage signal which the digital signal processor interpreted as a large delta V crash. Once activated, the unit generated a crash call. The suitcase system was utilized for three purposes; (1) to generate a large number of calls and to measure the crash notification time, (2) to routinely test the ACN system to ensure that it was working properly and (3) to provide ongoing training for the dispatchers so they were ready to deal with actual crash calls when they occurred Hundreds of suitcase calls were made during ACN program and many of those were logged as simulated crash calls. Figure 4-3 is a histogram showing the notification times for these suitcase calls overlaid with the notification times of the actual ACN crash calls. It can be seen that the mean notification time of the ACN crash calls was 44 seconds and the mean notification time of the simulated calls was 47 seconds There were several suitcase test calls that did have relatively long crash notification times (see Figure 4-3). It was determined that the long notification times were a result of heavy cellular network call traffic that resulted in long message transmission times The simulated crash message tests demonstrated that in 87% of the time, the ACN system completed the crash call in less than a minute.

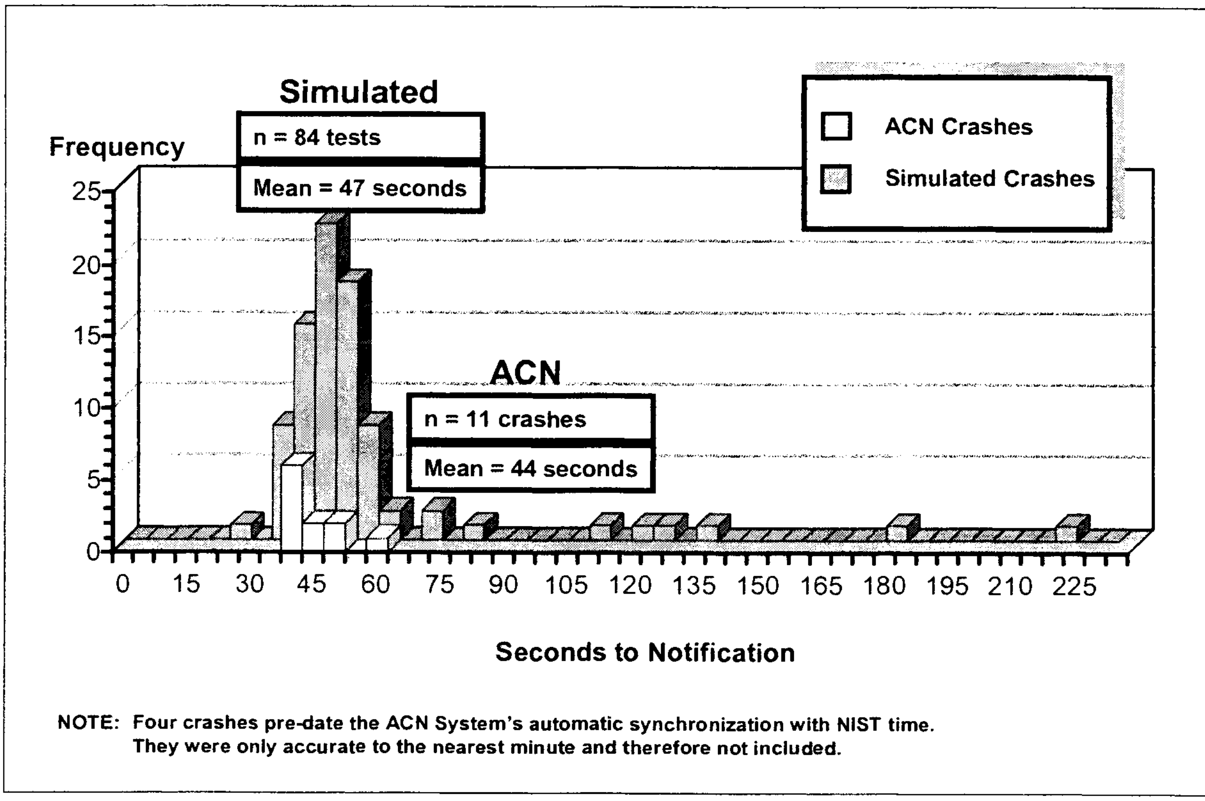

Figure 4-3. Histogram of Actual and Simulated ACN Crash Notification Times

It was hypothesized that any reduction in notification time due to ACN would be most significant in rural areas where travel distances are greater, the opportunity for secondary reports from passers-by is less, and the ability for vehicle occupants to know precisely where they are is reduced. This hypothesis is somewhat supported by national crash databases, such as the FARS, but has never been rigorously verified with quantitative data.

In order to test this hypothesis, it was necessary to define a more quantitative measure of "rural", and apply this definition to evaluate response times as a function of "ruralness." The measure that was created for this purpose tried to capture the most relevant attribute of "ruralness" from the perspective of crash notification. This attribute relates to the likelihood that the crash will be witnessed or found shortly following the crash event. This measure of "ruralness" was defined to be the Conspicuity Index.

The Conspicuity Index is a means of quantifying how "noticeable" a crash might be in a particular location. In this sense, "noticeable" means; the likelihood that someone will see, hear, or otherwise become aware that a crash has occurred and that help is needed. The term conspicuity is therefore defined to mean the innate characteristic of being observable in some way. It is defined as a function of the number of vehicles that pass by a particular crash site and by the number of people that live or work within sight and sound of the crash site. The Conspicuity Index is defined in Table 4-4.

Table 4-4. Conspicuity Index

Traffic Density	Roadside Development Level			
	Very Low = 0	Low = 1	Medium = 2	High = 3
None = 0	0	1	2	3
Low = 1	1	2	3	4
Medium = 2	2	3	4	5
High = 3	3	4	5	6

Traffic Density (at the time of the crash)

0 = no traffic, i e , an off-road location mostly or completely hidden from the road

1 = local, rural road with fewer than thirty cars per hour

2 = commuter road, village or business area, 30-120 cars per hour (1/2 – 2 cars per minute)

3 = heavily traveled road, main highway or urban business area, 121 or more cars per hour

Roadside Development Level

0 = no inhabited buildings in sight in any direction, no intersections within 200 meters

1 = few inhabited buildings in sight,

2 = several inhabited buildings in sight, homes and/or businesses, with space between them

3 = many inhabited buildings in sight, homes and/or businesses

Other Subtract 1 for:
crash times of 10:00 PM – 6:00 AM OR unlit road at night OR bad visibility due to weather

The Conspicuity Index was applied to evaluate the crashes experienced during the ACN operational test The results of this evaluation are summarized in Table 4-4 The traffic flow is shown in the column on the left side of Table 4-4 and is labeled Traffic Density The levels of traffic density are defined below the matrix The number of people who could have observed the crash, either immediately or within a short time, was estimated by quantifying the number and type of buildings near the crash site, i e , the Roadside Development The Roadside Development is shown across the top of the matrix in Table 4-4 and is defined below the matrix It should be noted that the Conspicuity Index score for a given location would be expected to vary with the time of day since traffic density will vary with time

Table 4-5 shows the Conspicuity Index and the notification time for the fifteen above threshold ACN crashes that occurred and for which notification time data is available Table 4-6 shows the same information for the 26 CET cases that occurred and for which there is notification time data In each of these tables the actual notification times are shown in the left most column while the calculated conspicuity parameters are shown in other columns

These data are plotted in Figure 4-4 with a line showing the trend for notification time of CET crashes as a function of conspicuity, i e , those crashes for which an ACN system was not available to provide immediate notification The difference between the CET notification time line and the ACN crash notification times is the expected time saved due to the ACN providing immediate notification of a crash

Table 4-5. Conspicuity Indices for ACN Crashes

Case	ACN Notification Time (min)	Traffic Density	Roadside Development	Poor Visibility	Conspicuity Index
1046	2	1	0	-1	0
1094	5	3	2	0	5
1104	1	3	3	0	6
1109	2	3	3	0	6
1205	0	3	3	0	6
1239	1	1	2	-1	2
1254	1	2	3	0	5
1268	0	3	3	0	6
1343	1	1	1	0	2
1463	0	3	3	0	6
1478	0	3	3	0	5
1707	0	3	3	0	6
1729	0	1	1	0	2
1760	1	2	1	0	2
1302	0	3	3	0	6

Table 4-6. Conspicuity Indices for CET Crashes

Case	CET Notification Time (min)	Traffic Density	Roadside Development	Poor Visibility	Conspicuity Index
00150	0	2	3	0	5
00685	2	2	3	0	5
00710	2	2	3	0	5
00776	30	1	0	0	1
00850	4	2	2	0	4
01077	0	3	3	0	6
01104	2	2	2	0	4
01135	2	2	2	0	4
01288	2	3	1	0	4
01469	3	3	2	0	5
01478	1	3	2	0	5
01610	1	3	3	0	6
02330	approx. 10	1	2	0	3
02344	2	3	3	0	6
02374	1	3	3	0	6
02571	4	3	2	0	5
02904	3	2	3	0	5
03136y	46	1	1	-1	1
03136z	0	2	2	0	4
3445	6	3	1	0	4
03733	2	3	2	0	5
04051	9	2	1	0	3
04112	2	1	1	0	2
04139	2	3	3	0	6
A1408	3	1	1	0	2
P037	12	3	2	0	5

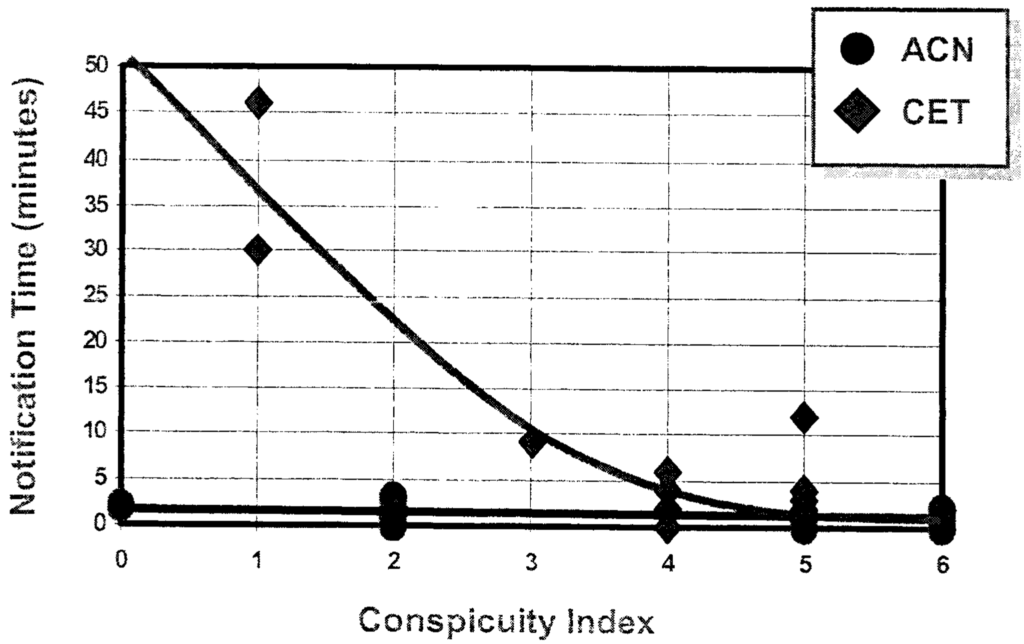

Figure 4-4. Notification Time versus Conspicuity Index

It can be seen that the ACN system notification times are always less than two minutes while the CET notification times have been as long as forty-six minutes The data are limited at this point, with only twenty-six CET cases, and therefore the trend is only suggested More data are needed before clear conclusions can be drawn about the relationship between conspicuity and notification time. However, if our hypothesis is correct, the ACN system can reduce the notification time, and consequently the emergency medical response time, significantly in instances where a crash occurs in an inconspicuous location.

5 Conclusions

The following paragraphs summarize the results of the project, present conclusions based on the results, and provide additional discussion of issues and lessons learned associated with the design and conduct of the Operational Test.

ACN Technology Works. As noted earlier, when this project was initiated there were no vehicles on American highways with ACN systems It was during this program that the first 'primitive' ACN systems, using air bag deployments to trigger the crash message, were offered commercially. To this day, the ACN technology developed and deployed in this Field Operational Test is the most advanced crash detection and characterization system. The Field Operational Test demonstrated that this technology works and has the potential to save lives on our highways The program demonstrated that ACN systems can measure vehicle accelerations in three dimensions, automatically alert PSAP dispatchers about the crash and then switch to voice so that the dispatcher can talk to the vehicle occupants By using crash data transmitted by the ACN device, injury estimation algorithms, and possibly information obtained from occupants of the vehicles, dispatchers can assess the probability that a serious injury crash has occurred

Over seven hundred ACN systems were deployed in privately owned, volunteer participant vehicles across the Western New York test area during the FOT. During the 3-year deployment period valuable information was obtained on the ACN system reliability and performance. While the ACN system worked well in most cases, there were instances in which crash messages were sent when no crash had occurred, or no crash message was received at the 9-1-1 center even though a crash had occurred. In five instances, ACN equipped vehicles experienced above threshold crashes and no message was received at the 9-1-1 center The reasons for these failures included: the receiving computer was disconnected at the 9-1-1 center; very poor cellular coverage at the crash scene, severe damage to the ACN system during the crash; and failure of the backup ACN battery. These crashes provided valuable information on potential system failure points. Two of the failures were attributable to the ACN system and may have been avoided by a more robust ACN design or a different equipment installation strategy. Two of the failures were due to circumstances beyond the control of the ACN system. One failure was of unknown causes. Valuable information was also obtained in those cases in which vehicles transmitted crash messages when no crash had occurred. This occurred with 31 of the 874 units (i.e., 3.5%) that were fielded. These cases were of great interest because one of the concerns of the public safety community was that they might receive large numbers of false crash calls if unreliable automated crash-messaging systems were widely deployed. The results of the ACN FOT experience indicated that all the false crash messages were attributable either to improper installation of accelerometers on the printed circuit board, inadequate signal conditioning, or voltage spikes that resulted from participants attempting to "jump-start" their vehicles. System modifications were developed that corrected these deficiencies and when modified systems were installed the false alarm rate was reduced.

Finally, in all but one crash, the existing Western New York AMPS cellular network and message routing capability was sufficient for getting messages to the appropriate PSAPs.

Automatic notification of crashes reduces notification times. The elapsed time between the crash and when the 9-1-1 dispatch center was alerted was defined to be the crash notification time. Prior research into crash response event timelines has been greatly hampered by lack of accurate information on the time of the crash. This is because crash times are based on estimates made by those involved (i.e., crash victims, witnesses, first responders). Since people are poor at estimating durations of time, especially during times of stress, these estimates are often inaccurate. For unwitnessed crashes that involve serious occupant injuries, the police at the scene must estimate the time of the crash. FARS data (based on these estimates) indicates that the national average for crash notification times is about 7 minutes for rural fatal crashes and 4.5 minutes for urban fatal crashes. However, there are wide spreads in notification times, ranging from less than a minute to several hours or more. In the FOT, we found that ACN consistently provides notification within two minutes as long as there is cellular coverage. The CET data collected during the FOT indicated that although urban and witnessed rural crashes are typically reported within a few minutes, unwitnessed crashes in rural areas can take much longer. During the ACN FOT most CET crashes occurred in urban areas and had notification times of a few minutes, although there were some crashes in which notification times of between 10 and 45 minutes were measured. ACN would have provided a significant reduction of response time for these crashes.

Public Safety community was able to successfully use ACN. The primary focus of the ACN program was the development and evaluation of the in-vehicle equipment. With that in mind, no attempt was made to optimally integrate the ACN message reception equipment with equipment existing in the participating 9-1-1 PSAPs. To the contrary, the ACN message reception equipment was operated as an independent, standalone system. Nevertheless, PSAP dispatchers quickly adapted their procedures to include the use of ACN technology. Dispatchers reported that having immediate notification of crashes with an accurate crash location improved their ability to provide rapid and appropriate emergency services.

Widespread deployment of ACN technology will require successful application of commercial models. ACN can provide immediate and accurate notification of crashes to PSAPs but only if people are willing to purchase the equipment and put it in their vehicles. This will be achieved when ACN systems are made available through successful commercial offerings. This means that the systems need to offer valued service at acceptable prices. It also requires that issues of privacy and liability be dealt with in a ways that do not create fears that make these systems unattractive.

Integration of commercial ACN systems with the public infrastructure is crucial to achieving maximum ACN benefits. The ability to deliver ACN emergency data electronically to the correct PSAPs avoids time-consuming and error-prone verbal protocols in use today. Integration with PSAPs is critical to ACN success. This will require the application of standard communications and operational protocols that are acceptable to the Mayday industry as well as the PSAP community.

The data available from systems like ACN can provide a wide range of benefits beyond simply dispatching first responders. One of the products of the ACN field Operational test has been to stimulate the EMS community to consider how ACN systems might further improve the delivery of emergency services. In addition to knowing crash occurrence and location, ACN systems can provide information that characterizes the crash severity. This information can aid dispatchers in deciding what equipment is needed (e.g., helicopter, jaws of life, multiple ambulances); provide information to prepare EMS staff for on-scene intervention and triage decisions; and support preparations at emergency medical and trauma care facilities. These data can also be provided to assist in traffic management and incident response functions (e.g., dispatching tow trucks, cleaning spills, repairing damage to roadway).

Voice and data systems offer significant advantages over those that are data-only. The availability of a voice connection between the PSAP and the distressed vehicle provides important advantages over data-only systems. First, it allows dispatchers to verify that there was a crash and to determine the extent of injuries (i.e., number of people injured and seriousness of injuries). This was apparent during the ACN FOT when the system malfunctioned and sent a crash message when none had occurred. With a voice link between dispatchers and vehicle occupants, the dispatcher was quickly able to confirm whether or not an emergency existed. In the event of a crash, the voice mode assists the dispatchers with decisions regarding what organizations should respond and with what type and quantity of personnel and equipment It may also allow dispatchers to gather information about the crash scene that is important in managing the response execution. For example information of interest could include: traffic lanes blocked as a result of the crash; conditions that increase the possibility of secondary crashes (e.g., heavy traffic, icy road, etc.); and fire or other hazards associated with the crash. For each of these cases a different set of response actions may be needed. Finally, and perhaps most importantly, the dispatcher can provide medical advice to the injured occupants and can assist frightened or confused occupants as needed.

Knowledge of direction of travel is important for optimizing emergency response execution. There are many situations in which emergency response can be more optimally executed with knowledge of the direction vehicles were traveling prior to a crash. This information enables the dispatcher to determine on which side of a divided highway the crash has occurred. Response times may be increased by several minutes if emergency response vehicles must re-deploy to an opposing lane or to roadway crossing via an overpass.

During the ACN FOT dispatchers were provided with locations for the 10 seconds prior to the crash as well as the location of impact. This was useful in providing information on the exact travel lane or roadway. This was especially important during the ACN FOT because GPS selective availability was not yet disabled and GPS location accuracy was only within about 100 meters. Although GPS selective availability is no longer used to degrade GPS for non-defense applications, it is still possible to confuse location without knowledge of direction of travel. This is true, for example, when a crash or emergency occurs under an overpass or overhanging structure because in these situations GPS accuracy is reduced, even without selective availability

Operational Tests Demand Special Focus on Operations. Because field operational tests involve operations in real world environments they demand special attention to operational issues that are not typically associated with research and development projects. These issues include: participant recruiting, operational integration, training and participant support, field system maintenance, and maintenance of participant relations. It is easy to underestimate the extent and full scope of these tasks. If an FOT involves participants from the general population recruiting can be a difficult task. Mechanisms for reaching out to desired populations need to be devised and implemented. Potential participants need to be contacted and educated about the goals, benefits, and requirements of the project. They also need to be trained and integrated within the project. An objective of the ACN program was to recruit 1,000 ACN participants and 4,000 CET participants. Many outreach methods and forums were employed to attract participants. Once volunteers were identified, efficient procedures were needed to install equipment and provide participants with ongoing program information to maintain their interest and support. In addition, it was necessary to establish help desk and field maintenance operations that could identify and deal with problems, as well as keep up with people changing vehicles and moving out of the test area. It is also necessary to monitor system performance to ensure operability throughout the test. This required periodic system tests and the ability to fix problems without disrupting ongoing operations. Termination of the project also required carefully planned procedures to ensure that all participants were notified that the test was ending and that they had to have their equipment removed or disabled.

Storehouse of Lessons Learned. The ACN FOT provided unique insights and lessons that can be applied to other operational tests and commercial Mayday system deployments. The FOT provided the first opportunity to evaluate systems that provided PSAPs with immediate notification of crashes, an accurate crash location, a description of the crash severity, an estimate of the severity of occupant injuries, and related vehicle and potential occupant information The insights gained during this test offer valuable guidance as ACN technology becomes more widely deployed It is hoped that this FOT will play a role in opening the door to future research that will allow full advantage to be taken of ACN technology

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AUTOMATED COLLISION NOTIFICATION (ACN)
FINAL REPORT

31 October 2000

APPENDIX A
Participant Outreach Material

Veridian Engineering

4455 Genesee Street
PO Box 400
Buffalo, New York 14225
716/632-7500
www veridian com

ISO 9001

ISO 9001 Certified

Flight Research
Transonic Wind Tunnel
Automotive Safety Test Equipment
Tire Research
Chemical Defense
HYGE Sled

Friday, July 21, 2000

Dear ACN participant,

On behalf of Veridian Engineering (formerly Calspan Corporation) and all its personnel involved in the Automated Collision Notification (ACN) test program here in Western New York I would like to thank you for your participation in ACN test program.

With your help the ACN test has been a great success. As you know the program was extended twice and we have been able to provide help to victims in over 20 crashes. The project's main purpose was to develop and evaluate state-of-the-art technology for sensing crashes and notifying emergency response agencies. As a result of the ACN tests the viability of the technology has been demonstrated along with approaches for efficient integration of this technology with public emergency response agencies. There are several initiatives that are now applying the results of the ACN test to provide improved crash sensing and emergency response mechanisms nationally. Without the help of volunteers like you, we could never gather the type of "real world" data necessary to make this endeavor a success.

They say that all good things must come to an end; the ACN test program is no exception to this. The last day of the ACN test will be September 30, 2000. Sometime between the last week in July and September 30th the automatic crash detection and notification portion of the ACN equipment in your vehicle will be remotely deactivated. The cellular telephone will remain functional for you to place and receive regular telephone calls. No action on your part is necessary to deactivate the system. You will not notice any indication that the system has been deactivated; the handset will still beep when the ignition is turned on.

Please be aware that after your ACN system is deactivated, should you be involved in an accident, THE ACN SYSTEM WILL NOT DETECT THE CRASH AND WILL NOT AUTOMATICALLY CALL FOR HELP. YOU WILL NEED TO DIAL 9-1-1 MANUALLY TO REQUEST ASSISTANCE.

After September 30th if your ACN system still has NOT been remotely deactivated for some reason (e.g., if equipment malfunctions or if your cellular service with CellularONE is discontinued), you will still need to call 9-1-1 manually for assistance in the event you are involved in an accident. This is because after September

30th the equipment used to receive the automated crash messages at the Erie County Sheriff's Office will no longer be operating. If your ACN system is NOT deactivated and you are involved in an accident that activates the ACN system the system will attempt to call for help. When it is unable to connect to the receiving equipment the handset in your vehicle will display the message "DIAL 9-1-1 MANUALLY".

CellularONE is pleased to announce that they will extend your current rate plan for as long as you maintain cellular phone service with them. New portable digital phones and their associated rate plans are available from CellularONE should you wish to upgrade to portable digital phone service. If you have questions about your cellular service, if you wish to upgrade your service, or if you wish to discontinue your cellular service, please contact Mr. Thomas Lozinsky, CellularONE Product Manager, at (716) 435-2469.

Enclosed with this letter is an End of ACN Test Program Waiver and Release Statement similar to the one you signed when you completed your application to participate in the ACN program. Please ***read it carefully*** and ***complete the yellow signature sheet***. Please fold the signed yellow sheet in half along the dotted line so that the Veridian Engineering return address shows and then tape closed. Please return the folded yellow sheet to Veridian Engineering in the mail (no postage is necessary). Please retain the End of ACN Test Program Waiver and Release Statement for your records.

Again let me take this opportunity to thank you for your participation in this important program. New developments in the field of Automated Collision Notification are occurring daily, all designed to make your travel safer. You have played an important part in this key US Department of Transportation sponsored test program that has pioneered this new technology.

Sincerely,

Alan Blatt

Mr. Alan Blatt
ACN Project manager

Encl (2)

VERIDIAN
ENGINEERING
ITS Group

Veridian Engineering
Transportation Sector
Intelligent Transportation Systems Group
Automated Collision Notification
Field Operational Test

End of ACN Test Program Waiver and Release Statement

For Test Participants

Please read the following carefully. It contains a description of how Veridian Engineering's (formerly Calspan's) Automated Collision Notification ("ACN") Field Operational Test (the "Test Study") equipment ("ACN equipment") will operate following termination of the Test Study and provides several important warnings to persons who are currently voluntarily assisting in the Test Study. It asks that persons currently participating agree to release Veridian Engineering and other sponsors of the program from any and all potential liability that may arise in connection with the termination of the Test Study.

A. Disclosures and Warnings

At the end of the Test Study, the cellular phone and ACN equipment will remain in your vehicle. The crash sensing equipment will be rendered inoperative by terminating the ACN signal. No calls to 9-1-1 will be made automatically in the event of an accident. Your cellular phone service will continue with CellularONE at your current rate plan. All repairs to the cellular phone can be performed by CellularONE.

B. Release and Waiver

I, the undersigned, hereby agree to release and hold harmless Veridian Engineering (formerly Calspan Corporation), CellularONE, the State of New York and the U.S. Department of Transportation and its component agencies, and each of their affiliates, officers, directors and employees, from all liability for accidents or injuries that arise in connection with or as a result of the termination of my participation in the Automated Collision Notification (ACN) Field Operational Test, including but not limited to claims or suits for personal injury, negligence, product liability or failure to warn of any dangerous conditions related to the test. This release is intended to waive all claims against Veridian Engineering and the other program sponsors listed above for negligence, warranty, failure to warn, strict liability or any other damages or compensation of any kind in connection with the test, the design, implementation and termination of the test, the equipment used in the test (including the cellular telephone) and the provision of any emergency service that results from notification of emergency services personnel because of activation of ACN equipment.

VERIDIAN
ENGINEERING
ITS Group

Read This Before Signing: The signature of the ACN Field Operational Test Volunteer must be witnessed by a person who knows the Test Volunteer. The Witness must also sign below.

Test Volunteer

Signature: ____ **Date:** ___________
ACN Field Operational Test Volunteer

Print Name: ____

Print ACN Phone No.: 440-_________

Witness

Signed before me on this _______ day of _________________, 2000.

Signature: ____
Witness

(Fold Closed Here)

MAIL THIS SHEET TO VERIDIAN

Tape Closed Here

Return To:

Automated Collision Notification Program

Veridian Engineering

4455 Genesee Street

Cheektowaga, NY 14225-1967

Tape Closed Here

ACN System News

Veridian Engineering, Calspan Operations Fall 1999

ACN Test Extended (Again)!

Some time ago, Automatic Collision Notification (ACN) equipment was installed in your vehicle as part of a research program Veridian Engineering, Calspan Operations is conducting in Western New York for the U.S. Department of Transportation National Highway Traffic Safety Administration. Since then, much has happened in the test program:

- **The ACN test has been extended in Western New York (WNY) for another year to September 2000!**
  As a participant in this test, your service with CellularOne will automatically continue—no further action is required on your part. Your ongoing involvement is greatly appreciated.
- **CellularOne continues to support the test.**
  CellularOne Buffalo continues to support the ACN program by installing equipment and providing wireless service.
- **Veridian has updated the ACN cell phone instruction pamphlet.**
  You will find the new and improved instructions for the cellular telephone inside this newsletter. Please review them to know what to do in the event of a crash.
- **Veridian and CellularOne have taken steps to rectify previous problems.**
  This program is a test of new technology and new cellular services. If problems occur, we will, as in the past, take steps to overcome them. If you experience any difficulties, contact CellularOne's Peter Pidgeon at 716-435-2422 (for billing problems) or Veridian's Roger McClellan at 716-632-7500, ext. 5304 (for ACN equipment problems).

(Continued on page 2)

Veridian Hosts NHTSA Head Martinez and Dateline NBC

This spring, Dateline NBC came to the Veridian Engineering Transportation Group crash test facilities in Buffalo, New York to do a story on the lethal nature of side impact crashes. During the visit, Dateline NBC's Consumer Correspondent Lea Thompson interviewed Dr. Ricardo Martinez, Administrator of the National Highway Traffic Safety Administration (NHTSA), and Veridian's Transportation Sciences team staged a formal Government-certified side impact crash as part of the ongoing the New Car Assessment Program (NCAP) conducted by the Transportation Sciences Division of the Transportation Group.

In addition, at Dr Martinez's specific request, Dateline NBC taped a separate interview with him that day, answering several questions regarding a piece on ACN programs filmed earlier by Dateline NBC's Laurel Bowman. Dr. Martinez was keenly interested in, and quite persistent about, having the opportunity to provide an on-camera quote in support of the ACN program for this yet-to-be-aired Dateline NBC story. He acknowledged the superiority of Veridian Engineering's ACN technology over current market offerings and endorsed the Veridian device as a "next generation system."

Dateline NBC filmed the NCAP side impact test in real time as it was conducted by the Transportation Sciences team and then interviewed Dr. Martinez. Dateline NBC producer John Grecco expects the Veridian piece to air sometime in early autumn.

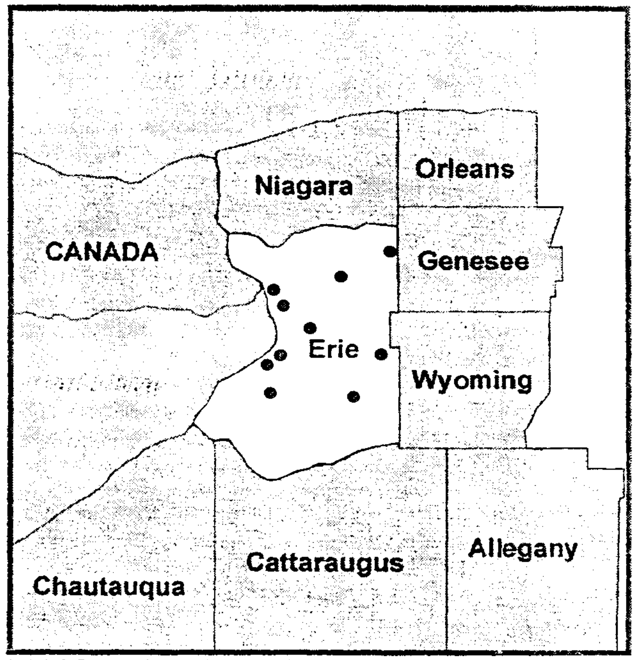
From left to right: Dateline NBC's Lea Thompson, NHTSA Head Dr. Ricardo Martinez, Veridian Engineering's Director of Transportation Sciences Sam Pugliese

ACN Test Extended (cont.)

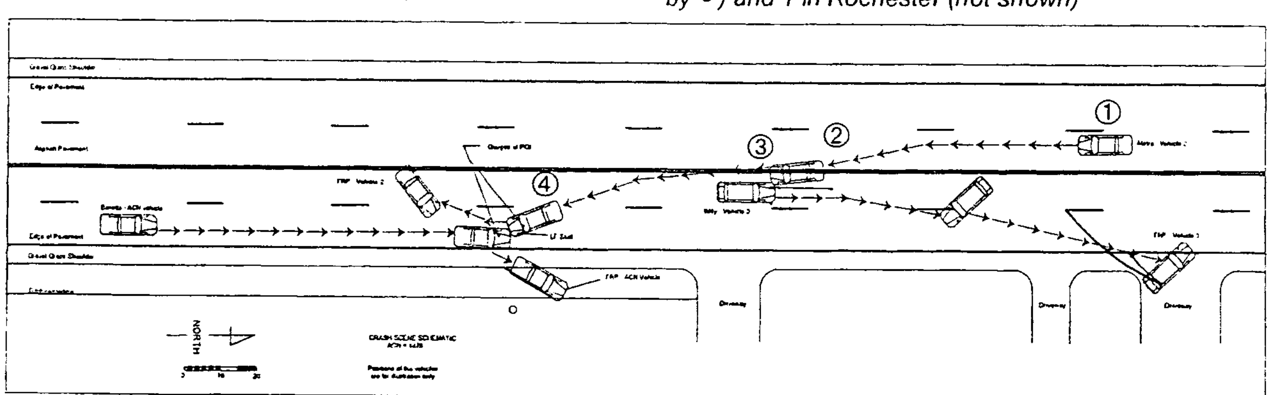
- **Over 700 ACN systems have now been installed!**
  However, we are still looking for volunteers. If you know anyone who would be interested in participating in the program, please use the inserted application form or call the ACN Message Center at (716) 631-4111 Applications will be accepted until December 31, 1999
- **The Minnesota DOT has implemented a Mayday system based on the ACN.**
  The Minnesota DOT and State Patrol, Mayo Clinic, and Veridian recently developed, installed, and are testing Mayday Plus, a system that combines automatic crash notification with emergency response (ER) and 9-1-1 services. Although Mayday Plus is similar to the ACN program, it concentrates on assessing the effectiveness of the ER network rather than the reaction time of ER personnel.
- **There have been eleven successfully reported collisions.**
  In addition to the 11 successfully reported crashes (10 in Erie County and 1 in Rochester), there have been 37 minor crashes that did not activate the system because the crashes were not severe enough to cause activation.

A sample case study (see pictures and diagram) was a multiple vehicle crash that involved an ACN-equipped 1992 Chevrolet Beretta, a 1998 Chevrolet Metro, and a 1940 Willys classic car. The crash occurred in the northbound lanes of a four-lane roadway in a suburban area of the Erie County test region. The driver of the southbound Metro lost control (due to a heart attack), drifted left across the center of the road, and struck the left front corner of the Willys The Metro continued into the northbound lanes and then struck the left frontal area of the Beretta at approximately 20 mph.

The ACN system in the Beretta detected the crash and notified the Erie County Sheriff's Department and the Medical Emergency Response System (MERS) at ECMC Voice communication between the ACN vehicle and the Sheriff's department was established (the dispatcher spoke to the driver and informed her help was on the way) and multiple police, fire, and ambulance units responded to the scene



WNY Crash Locations. The system successfully reported 10 accidents in Erie County (locations shown by ●) and 1 in Rochester (not shown)



Crash Schematic

The southbound Metro lost control (1), drifted left of the road centerline (2), and struck the left front corner of the Willys (3) The Metro continued into the northbound lanes and then struck the left frontal area of the Beretta (4).

(Continued on page 3)


ACN-Equipped Beretta

ACN SYSTEM NEWS
Veridian Engineering
Transportation Group
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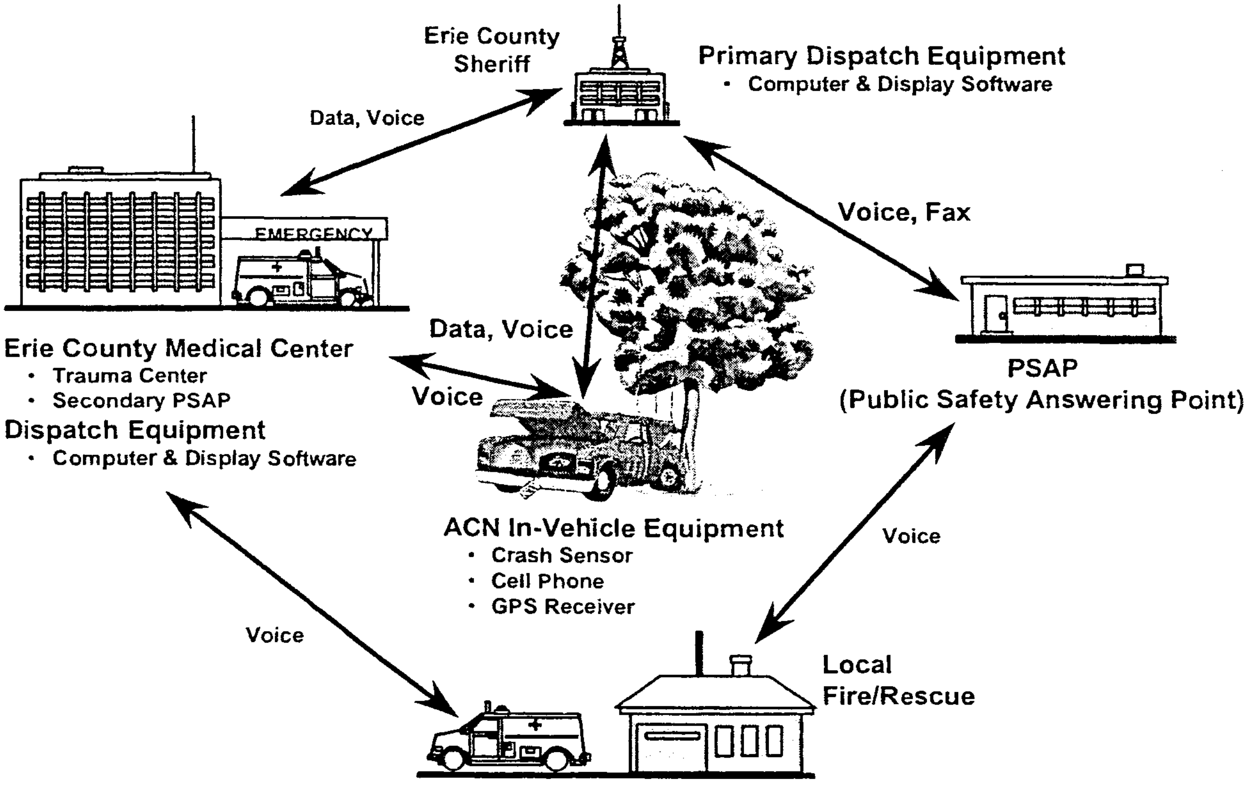
Addition to the mailing list or additional copies of this newsletter may be requested by contacting Sandra Bellman at the address or phone number listed above address

How the ACN System Works.

After a vehicle crashes, collision location, direction, and severity information is automatically transmitted by the ACN to the Erie County Sheriff Department dispatcher and relayed to appropriate emergency services personnel.



Please Note: If you are relocating outside of WNY, please tell us **before** you move We are unable to shut off or transfer the cellular phone service without prior notification.

Also, if your window is replaced or otherwise altered in such a way that your ACN sticker is destroyed, please contact Veridian Engineering and we will replace your sticker.

If you know anyone who would be interested in participating in this program, or if you have any questions or comments, please contact ACN Message Center at (716) 631-4111; write to ACN Test, Veridian Engineering, P.O. Box 400, 4455 Genesee Street, Buffalo, New York, 14225; or visit the ACN website at http://www.calspan.com/acn html.

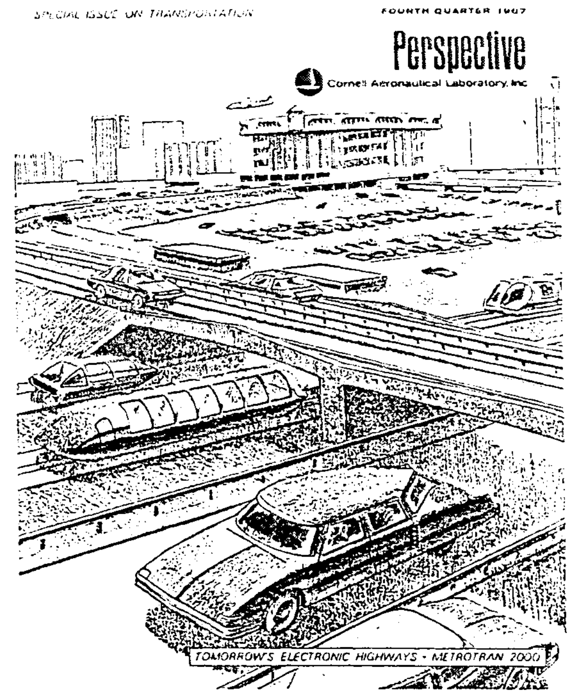
Thank you for helping support this important program.

Eye on History

Among Veridian Engineering's many accomplishments, the company could be credited with helping to lay the foundation for today's Intelligent Transportation System (ITS) programs. The company's 50-plus-year history of transportation research includes a 1963 study of a transportation system called "Metrotran 2000" which was a conceptual metropolitan transportation system "of the future."

Much of the Metrotran 2000 study related to possible future systems for metropolitan areas where land, water, and air modes of transportation meet at interchange terminals called "modemixers."

Eventually, many of the concepts introduced in Metrotran 2000 study became the basis for the U.S. Government's Mobility 2000 project, which developed into Intelligent Vehicle Highway Systems (IVHS). IVHS has, in turn, spawned the current ITS program which has incorporated the concepts from the Metrotran 2000 study conducted over 35 years ago.



Veridian (then Cornell Aeronautical Lab) newsletter describing Metrotran 2000

Veridian Engineering
P.O. Box 400, Buffalo, NY 14225

CET NEWSLETTER

Veridian Engineering, Calspan Operations Fall 1999

CET Test Extended (Again)!

Some time ago, a Crash Event Timer (CET) was installed in your vehicle as part of a research program **Veridian Engineering, Calspan Operations** is conducting in Western New York for the **U.S. Department of Transportation National Highway Traffic Safety Administration**. Since then, much has happened in the test program:

- **The CET test has been extended in Western New York for at least another year!**
  Your ongoing involvement is greatly appreciated. Also, **we are still looking for volunteers**. If you know anyone who would be interested in participating in the program, or if you know of any not-for-profit organizations holding events at which CETs could be installed (such as fundraisers), please call Roger McClellan at (716) 631-4192; Veridian will pay the organization $3.00 for each CET they install!
- **Veridian has updated the CET instruction card.**
  You will find the new and improved instructions inside this newsletter; please review them to know what to do in the event of a crash and keep the instruction card in the glove compartment of the vehicle equipped with the CET.
- **CETs have collected EMS (Emergency Medical Service) response time data in many accidents.**

One of these accidents, for example, was a three-vehicle crash of a CET-equipped 1990 Ford Probe, a 1989 Chevrolet van and a 1995 Ford pickup. The force of the crash was above the timer's threshold and the CET was activated

The crash occurred at the intersection of a five-lane north/south roadway and a two-lane east/west road (see **Figure 1**).

The Ford Probe was southbound in the left-turn lane. The driver became distracted and turned left in front of the Chevrolet van. The van struck the right side of the Probe (see **Figure 2**) and then contacted the Ford pickup in a minor secondary collision. The Probe was towed from the scene due to disabling damage, but the van and pickup were driven from the crash scene by their respective drivers.

The crash did not cause any injuries to the vehicles' drivers; however, EMS personnel were dispatched. Based on data from the vehicle's CET, it was determined that EMS personnel were dispatched four minutes after the crash.

Figure 1· Northward view of the crash scene.

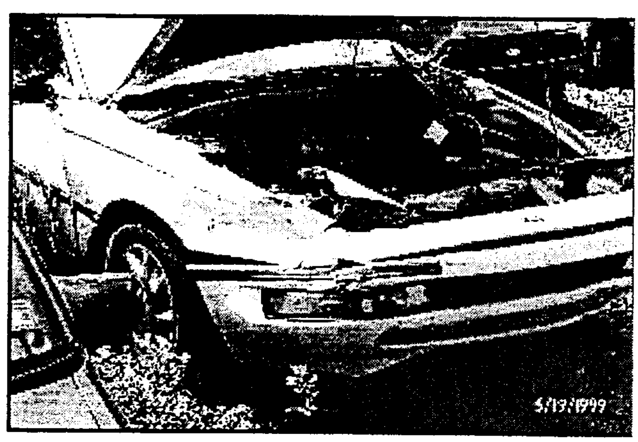


Figure 2: Right front view of the Ford Probe

How the CET Works

The CET determines the exact time an accident occurs, enabling Veridian Accident Investigators to measure the time that elapses from the instant of the crash occurrence until Emergency Medical Service (EMS) personnel are notified of the crash This information has never been available before and is extremely valuable in EMS research It is providing particularly relevant information for rural, unwitnessed accidents where the amount of time that passes before EMS personnel are notified is longer and usually unknown.

The CET is a simple device that consists primarily of

- A radial inertia switch (which senses a crash and starts the timer)
- A microcontroller (count-up timer)
- A battery
- Two wire leads (used to transfer the crash time data onto a computer)

In the event of a crash, a small sticker placed on the driver-side rear window instructs EMS personnel to notify Veridian. However, test participants such as yourself should also notify Veridian by calling 1-800-383-COLL as soon as possible after the accident The CET **only retains recorded data for 3 weeks**, after that time, the crash data will be lost

If you are relocating, please tell us **before** you move so we can retrieve the CET and keep an up-to-date database

Also, if your window is replaced or otherwise altered in such a way that your CET sticker is destroyed, please contact us and we will replace your sticker

If you have any question or comments about the CET program, if you are changing vehicles or if you have changed your address, please contact our Message Center at (716) 631-4111 or write to CET Test, Veridian Engineering, P O Box 400, Buffalo, NY 14225

Veridian Engineering
P O. Box 400, Buffalo, NY 14225

Breaking CET News!

ACN System News

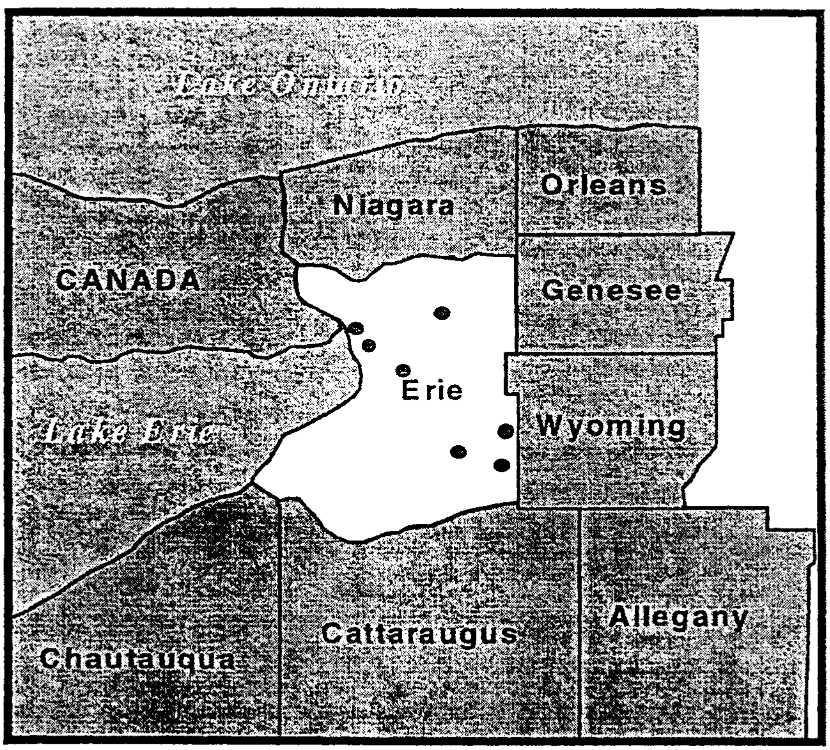
Calspan, an Operation of *Veridian* Summer 1998

ACN Test Extended!

Hello ACN Volunteer!

Some time ago, Automated Collision Notification (ACN) equipment was installed in your vehicle as part of the research program **Calspan, an Operation of Veridian,** is conducting in Western New York for the **U.S. Department of Transportation National Highway Traffic Safety Administration (NHTSA)**. Since then, much has happened in the test program:

- **The ACN test has been extended in Western New York for another year!**
  As a participant in this test, your service with CellularOne will automatically continue--no further action is required on your part. We would greatly appreciate your continued involvement. See our handy ACN User Guide included inside.
- **CellularOne will continue to support the test.**
  CellularOne Buffalo continues to support the ACN program by installing equipment and providing wireless service.
- **Over 500 ACN systems have been installed since last September.**
  While we appreciate this response, we are still looking for another 500 volunteers. If you know anyone who would be interested in participating in the program, please use the inserted application form or call Calspan at (716) 631-4111.
- **There have been eight reported collisions.**
  The system worked as intended in all of the accidents except one which occurred outside of the test area (in Chicago, Illinois).



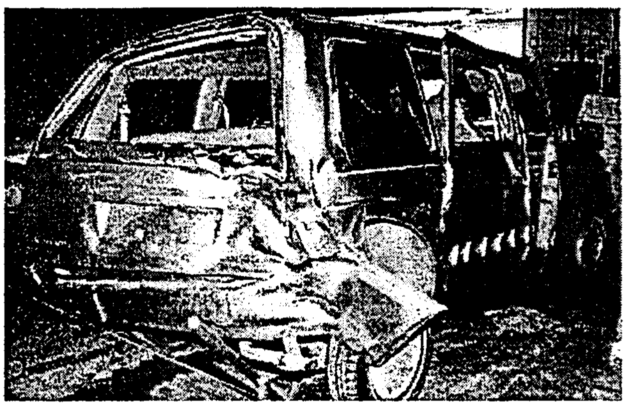
Crash Locations. *The system worked as intended in all of the WNY accidents (locations shown by ●)*

The ACN Team:

Calspan, an Operation of Veridian; CellularOne; National Highway Traffic Safety Administration; Erie County Sheriff's Department; Erie County Medical Center; Datumtech; New York State Department of Transportation

In one of these accidents, the driver rolled his car on a rural road late at night (see photo at right) and found that he was glad to have an ACN in his car: "I got the belt unbuckled and started moving around and someone was talking to me over the telephone. It was a dispatcher from 911. (The dispatcher) asked if everyone was O.K. That made me feel very secure because, once I heard the voice talking to me, I knew I didn't have to panic anymore and I realized people were on the way to help me."

An ACN helped emergency services personnel locate this Chevy Cavalier on a rural highway in Erie County late at night.



Damage to an ACN-equipped Plymouth Voyager

In another crash, emergency medical services personnel, alerted by the ACN, dispatched 3 ambulances to the accident scene involving this Plymouth Voyager (see photo at left).

- **Calspan is taking steps to rectify previous billing problems.**
  Thank you for your patience while we address a few problems concerning test calls made in the "roam" mode.
- **The program has had significant media coverage.**
  Segments on the ACN have appeared on ABC's "Good Morning America" program, various radio programs, and the local news, in addition to articles in national magazines and newspapers.

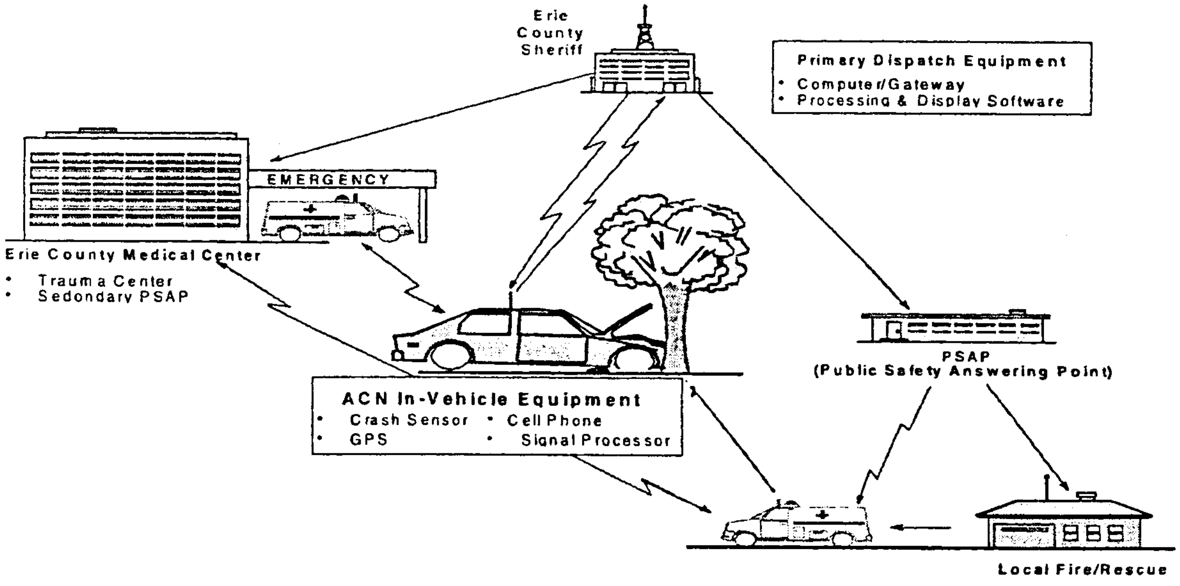
"Good Morning America" crew filming a simulated ACN crash

Attending the "Good Moming America" filming are (left to right). Erie County Sheriff Pat Gallivan, Congressman Jack Quinn, NHTSA Head Rick Martinez, Calspan General Manager Jack Wagner

- **Due to the successful experience gained in the ACN test, the program may be tested nationwide.** A bill is currently before Congress which, if passed, may provide funding for expansion of the program to test the feasibility of providing automated collision notification services across the United States.

How the ACN System Works.

After a vehicle crashes, collision location, direction, and severity information is automatically transmitted by the ACN to the Erie County Sheriff Department dispatcher and relayed to appropriate emergency services personnel.



Thank you for helping support this important program.

If you know anyone who would be interested in participating in this program, or if you have any questions or comments, please contact Calspan at (716) 631-4111; write to ACN Test, Calspan Corporation, P.O. Box 400, 4455 Genesee Street, Buffalo, New York, 14225; or visit the ACN website at http://www.calspan.com/acn.html.

Eye on History

During the early 1950s, engineers at Cornell Aeronautical Laboratory (later to become Calspan) used this crash simulation device to study the motions of articulated dummies, dubbed "Thick Man" and "Half Pint." A specially designed crash snubbing device brought this 1950 car to a sudden stop, as in a crash, with the use of cables.

Pioneering auto safety research in the mid-1950s included evaluation of padding materials for use in cars; development of safety door locks; and development of an auto seat-belt kit, which was manufactured and marketed by an industrial concern. At this time, the Laboratory's background in aircraft stability and control was applied to research on handling characteristics of cars, and a tire test, developed for the Air Force, was used to test tires for many commercial tire makers.

ACN System News
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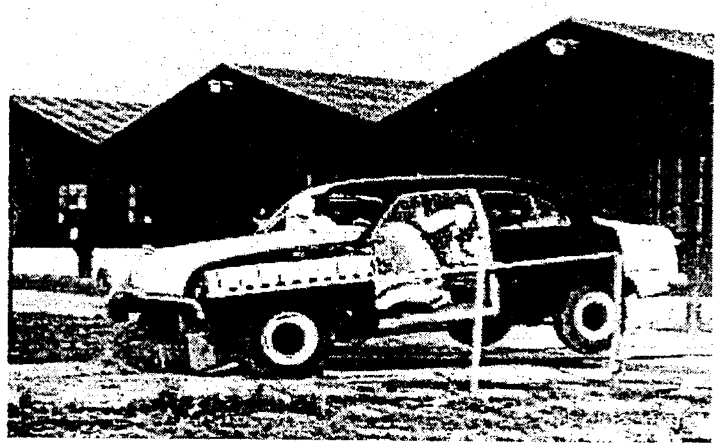
Addition to the mailing list or additional copies of this newsletter may be requested by contacting Sandra Bellman at (716) 631-4198 or at the above address.



Forty-five years ago, the company used this crash simulator to study occupant motion during accidents.

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February 2001

Automated Collision Notification (ACN) Field Operational Test (FOT) Evaluation Report

Technical Report Documentation Page

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16 Abstract

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) conducted the Independent Evaluation of the Automated Collision Notification (ACN) Field Operational Test (FOT) for the National Highway Traffic Safety Administration (NHTSA). The goal of ACN is to use technology to provide faster and smarter emergency medical responses in an attempt to save lives and reduce disabilities from injuries To attain this goal an ACN system should automatically determine that a motor vehicle has been in a collision, notify emergency response personnel of the collision and the vehicle location, provide information concerning the crash, and establish a voice link between the vehicle and emergency response personnel Information that might be provided about the crash includes estimates of crash severity and the probability of serious injury

The purpose of the ACN FOT was to demonstrate the feasibility of fielding an ACN system and the benefits of an ACN system to victims of motor vehicle crashes The ACN FOT was initiated in October 1995 with the first installations of ACN systems in vehicles starting in June of 1997 This report evaluates the results of the ACN FOT using data collected through the end of the test period in August of 2000 itiated in October 1995 with the first installations of ACN systems in vehicles starting in June of 1997 This report evaluates the results of the ACN FOT using data collected through the end of the test period in August of 2000 The ACN FOT and current activity in the commercial marketplace have demonstrated that the development and deployment of ACN systems is technically feasible The potential benefits of an ACN system result from reduced PSAP notification times, improved knowledge of the vehicle location, and estimates of crash severity and the probability of serious injury

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400 Seventh Street, S W
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AUTOMATED COLLISION NOTIFICATION (ACN) FIELD OPERATIONAL TEST (FOT) EVALUATION REPORT

POWER PROJECTION SYSTEMS DEPARTMENT
THE JOHNS HOPKINS UNIVERSITY • APPLIED PHYSICS LABORATORY
11100 Johns Hopkins Road, Laurel, Maryland 20723-6099
Operating Under Contract DTFH61-95-C-00098 with the Department of Transportation

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AUTOMATED COLLISION NOTIFICATION (ACN) FIELD OPERATIONAL TEST (FOT) EVALUATION REPORT

By: L R. Bachman
G.R. Preziotti

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01-022 (P)

THE JOHNS HOPKINS UNIVERSITY • APPLIED PHYSICS LABORATORY
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ABSTRACT

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) conducted the Independent Evaluation of the Automated Collision Notification (ACN) Field Operational Test (FOT) for the National Highway Traffic Safety Administration (NHTSA). The goal of ACN is to use technology to provide faster and smarter emergency medical responses in an attempt to save lives and reduce disabilities from injuries. To attain this goal an ACN system should automatically determine that a motor vehicle has been in a collision, notify emergency response personnel of the collision and the vehicle location, provide information concerning the crash, and establish a voice link between the vehicle and emergency response personnel. Information that might be provided about the crash includes estimates of crash severity and the probability of serious injury.

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KEYWORDS: Automated Collision Notification (ACN)
Intelligent Transportation Systems (ITS)

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EXECUTIVE SUMMARY

ES.1 INTRODUCTION

In 1998 there were 41,471 fatalities and an estimated 3,192,000 persons injured in police reported motor vehicle traffic crashes (Reference 1). It has been reported that of the approximately 42,000 crash deaths per year, nearly 20,000 die before receiving hospital care and that many of the remaining 22,000 people die after reaching a hospital too late to be saved (Reference 2). In addition, Reference 2 reports that it is estimated that 250,000 of the crash injuries are life threatening and that the economic costs of crash injuries each year amount to an estimated $100 billion dollars.

The goal of Automated Collision Notification (ACN) is to use technology to provide faster and smarter emergency medical services (EMS) responses in an attempt to save lives and reduce disabilities from injuries. This can be accomplished by both reducing the response time for providing emergency medical assistance to victims of motor vehicle crashes and providing information, such as estimates of crash severity and the probability of serious injury, to improve the response. To attain this goal an ACN system should automatically determine that a motor vehicle has been in a collision, notify emergency response personnel of the collision and the vehicle location, provide information concerning the crash, and establish a voice link between the vehicle and emergency response personnel.

The National Highway Traffic Safety Administration (NHTSA) Office of Vehicle Safety Research conducted the ACN Field Operational Test (FOT) to demonstrate the feasibility of fielding an ACN system and the benefits of an ACN system to the victims of motor vehicle crashes. The ACN FOT Program was initiated in October 1995 and ACN systems were deployed in vehicles in the test area from July 1997 through August 2000. The Johns Hopkins University Applied Physics Laboratory (JHU/APL) was selected by NHTSA to be the Independent Evaluator for the ACN FOT and has produced this evaluation report to address the performance of the ACN system. It should be noted that the architecture choice for the ACN FOT and the equipment developed for it were based on what was technologically and financially feasible for this FOT and were not meant to be the choice for future deployed ACN systems. Any attempt to extend the results of this FOT to future ACN system deployments should be undertaken with caution and consideration for the effects of the architecture chosen and the equipment developed for the deployments.

ES.2 TEST DESCRIPTION

An ACN FOT Team, led by Veridian Engineering, was selected by NHTSA to design, build, install, and conduct the operational testing of an ACN system in Erie County, New York. An ACN system may be viewed as consisting of an in-vehicle ACN system that determines that a crash has occurred and initiates a request for assistance, and the response network used to deliver the crash notification message and generate an EMS response. The in-vehicle system contains a crash sensor to determine that a collision has taken place, a location system to determine the position of the vehicle, and a wireless communications system to send the crash notification to the appropriate Public Safety Answering Point (PSAP) for emergency response dispatch.

Figure ES-1 shows the in-vehicle system used by Veridian for the ACN FOT. It determines location using a Global Positioning System (GPS) receiver, senses a crash with accelerometers dedicated to the ACN function, and communicates with the PSAP via a cellular phone. The in-vehicle system applied the output of its accelerometers to an algorithm that computed a measure of the severity of a possible crash based on the vehicle acceleration history. This severity measure was compared to a threshold based on an estimate of injury risk being exceeded to determine the occurrence of a crash. The threshold varied depending on the change in velocity and principal direction of force for the crash. Once a crash was detected, a data message containing the vehicle location, information characterizing the crash (i.e., change in velocity, principal direction of force, and rollover occurrence), and the vehicle cellular phone number was sent to the Erie County Sheriff's Office, the PSAP for the FOT. Once the data message was delivered, the system automatically switched to voice mode providing the vehicle occupants with a hands-free voice line with the PSAP.

Figure ES-1 Veridian ACN In-Vehicle Equipment Suite

The crash notification calls were made via a 1-800 number to a single regional message center for the Erie County area - the Erie County Sheriff's Office. This ACN FOT response network architecture was based on what was technologically feasible and financially affordable for the FOT and a desire to avoid changes to the emergency response system during this technology demonstration. It was not meant to be the architecture choice for future deployed ACN systems.

Upon receipt of an ACN call at the Sheriff's Office 9-1-1 Dispatch Center, a computer console displayed a detailed road map with the vehicle's last location, a series of past locations, and data characterizing the crash. The displayed data included the change in velocity experienced by the vehicle; whether the crash was a frontal, side, or rear impact crash; whether a rollover occurred, the make, model, and year of the vehicle; and the probable occupants of the vehicle. The Sheriff's Office dispatcher then had the opportunity via the voice line to confirm the nature of the emergency and obtain additional information (e.g., number of cars and occupants involved in the crash and confirmation of the crash location) prior to alerting the appropriate response agency of the emergency.

The FOT included two major data collection efforts. The first collected data on crash notification and EMS response times for vehicles without an ACN system, using Collision Event Timers (CETs), providing a baseline against which to judge the performance of the ACN system. The second collected data on crash notification and EMS response times for vehicles equipped with ACN systems. The CET was a relatively simple and inexpensive device that used an inertial switch to sense the occurrence of a crash and start a processor counting elapsed time from the start of the event. Veridian, when notified of the crash by either the driver of the CET-instrumented vehicle or law enforcement officials, sent a team to read the elapsed time counter and convert it to the time of the crash. This information was then used with data collected from PSAPs and EMS service providers to accurately determine the crash notification and EMS response times. CETs were installed in about 2,600 vehicles during the CET test period (August 1996 through August 2000) with most installations occurring between August 1996 and December 1997.

ACN in-vehicle systems were installed in about 700 vehicles during the ACN test period (July 1997 through August 2000). About 500 systems were installed during the first year of the test period, and the high of slightly under 700 vehicles was reached in April 1999. Data supporting the evaluation of ACN system performance was collected automatically from the ACN in-vehicle system and the Sheriff's Office Dispatch Center and manually from the PSAPs and EMS service providers. In addition, experienced crash investigation teams from Veridian reviewed all crashes involving ACN-equipped vehicles, inspecting all involved vehicles and the crash scene; interviewed police, EMS dispatchers, and fire/rescue personnel; collected notification and response times of emergency services; analyzed dispatcher emergency message records; and obtained injured victim medical records.

ES.3 ACN SYSTEM PERFORMANCE

The data sample available for analysis from this FOT was considered to be too small to enable significant conclusions to be drawn. There were only 15 ACN crashes available for analysis of PSAP notification times, and the number of samples available for other EMS response times was even smaller. The sample size for the baseline response time data collection effort was also extremely small. There were only 25 CET notification times available for analysis. Nevertheless, it can be stated that the ACN system worked as expected. The CDF at the Erie County Sheriff's Office was successfully notified in 16 of the 21 ACN crashes for a success rate of 0.76. The five failures were due to: (1) insufficient cellular phone coverage at the crash location, (2) damage inflicted to the ACN in-vehicle system during the crash, (3) low vehicle battery voltage when the backup battery was not available due to corroded terminals, (4) a disconnected telephone line to the modem in the ACN dispatch center equipment at the Erie County Sheriff's Office, and (5) unknown causes. The ACN system success rate would improve to 0.80 if the anomalous failure due to the disconnected telephone line is removed from the test sample.

The ACN system notified the CDF within 2 minutes of the reported crashes and it was noted that after the CDF computer was synchronized to a standard time source partway through the FOT, all notifications were within 1 minute. This performance was consistent with what was expected for the system. The average baseline notification time from the CET evaluation was 5.6 minutes. While the majority of the CET notifications were within 3 minutes, the distribution of CET notification times included a number of larger times (9, 12, 30, and 46 minute times were included in the limited test sample).

There were 31 false notifications made to the CDF for a non-crash event during the FOT. Veridian Engineering attributed these false alarms to faulty accelerometer mounting in the in-vehicle system or unstable or intermittent power supplied to the in-vehicle system. This number of false alarms would most certainly result in a false alarm rate considered unacceptable in a system with widespread deployment. However, it is likely that improvements in the production process and hardware design could significantly reduce the false alarm rate from that experienced in the developmental equipment used in this FOT.

In summary, it can be stated that:

a. The ACN in-vehicle system worked as expected. It was able to sense that a crash had occurred, determine the vehicle's position, and deliver a crash notification message to the FOT 9-1-1 dispatch center via a cellular telephone call that was then switched to a voice line.

b. The crash detection algorithm detected all but one injury crash during the FOT [an Abbreviated Injury Scale Level One (AIS-1)] and reduced the notification of property damage-only crashes by more than 85%.

c. The ACN system produced an average PSAP notification time of less than 1 minute. This average notification time was significantly less than the observed times for a number of the CET crashes.

d. The ACN system success rate was in the range of 0.76 to 0.80. Failure mechanisms included expected cases of insufficient cellular phone coverage at the crash location and damage inflicted to the ACN in-vehicle system during the crash. It should be noted that the small data sample size for the FOT limits the statistical significance of this result.

e. The ACN in-vehicle system produced an unacceptable number of false alarms during the FOT; however, it is likely that improvement in the production process and hardware design could significantly reduce the false alarm rate from that experienced in the developmental equipment used in this FOT. A need for improving the reliability of the developmental ACN dispatch center equipment was also noted during the FOT.

ES.4 INSTITUTIONAL ISSUES

The major institutional issues noted during the ACN FOT that could impact the development and deployment of ACN systems were:

a. ACN system liability

b. Access to ACN data

c. Ability of drivers to understand the ACN technology.

The first two ACN system issues were raised during the planning phase of the FOT. As the ACN FOT system was an experimental prototype; there were concerns raised over potential liability if the ACN system failed to work or if help was not provided in time to injured participants. The cause for this issue was the litigious society that we live in; the legal foundations for these concerns were not addressed. The second potential issue was based on the fact that the ACN system for the FOT collected data that could provide information concerning collisions and the operation of the vehicle (e.g., position, velocity, heading, and acceleration). There was a concern that the data collected during the FOT would be subpoenaed during litigation involving ACN-equipped vehicles in an attempt to establish fault in a crash.

While neither of these issues arose during the FOT, they remain potential concerns for future ACN deployments. Actions taken during the FOT in response to these concerns included designing the ACN System to be safe and reliable and to not change the way emergency responders deal with highway emergencies. In addition, Veridian Engineering developed a Disclosure and Warning Statement and Waiver using proper legal terminology to be signed by owners of ACN-equipped vehicles and a witness. The disclosure and warning statement noted that the ACN system was an experimental system and there could be instances where this experimental system fails or does not perform to expectations. The waiver also granted Veridian Engineering the right to use any and all data gathered from the FOT, with the exception of revealing the participant's identity or personal information to persons other than the participants in the program.

Other approaches to mitigating liability for ACN systems noted during the project include the development of accepted operating standards, dispatcher and notification center certification standards, and accepted procedures and protocols for interfacing and coordinating between private and public emergency response systems. It is also recommended that as requests for ACN data are to be expected, the architecture of future ACN systems should either support the provision of this information, or the ACN systems should not collect or save data that could be used against drivers. In the former case, the recruitment/sales literature should state the information that is available and the policies and procedures for the provision of this information. This issue will need to be resolved, not only for ACN applications, but also for many other Intelligent Transportation System (ITS) applications.

It was also noted during the ACN FOT that some owners of ACN-equipped vehicles had difficulty understanding how the system operated and the types of crashes for which an ACN response would be generated. It is suggested that future ACN deployments generate improved operating instructions and attempt to better educate the public about the capabilities of ACN systems and how they operate. In addition, other possible methods for resolution of this issue include adding an indicator to the in-vehicle ACN equipment to indicate that a crash has been sensed but that no emergency call is being placed due to the low likelihood of injury, and adding a single-button, manual crash-reporting capability to the ACN system.

ES.5 SUMMARY

The development and deployment of ACN systems is technically feasible. This was demonstrated in the ACN FOT and is supported by current activity in the commercial marketplace. The potential benefits of an ACN system would result from reduced PSAP notification times, improved knowledge of the vehicle location, and estimates of crash severity and the probability of serious injury.

Since the ACN FOT was initiated in 1995, commercial crash notification services have entered the marketplace. The first were offered in 1996 and based notification on air bag deployment or manual activation, thus limiting the types of crashes for which automatic notification is possible. The crash notification message in these systems is delivered to a private response center via cellular telephone. The response center then establishes a voice connection to the appropriate PSAP for EMS dispatch based on the vehicle's location and relays the information in the data message. Future versions of these systems could use accelerometers (or other sensors) dedicated to the ACN function similar to those used in the FOT, allowing a greater variety of crashes to be automatically detected and potentially providing estimates of crash severity and the probability of serious injury.

These commercial crash notification systems utilize private response networks, as the 9-1-1 system does not currently allow ACN calls to be delivered directly to a PSAP by dialing 9-1-1. It should be noted that this process of going through a private response center, instead of directly to a PSAP via 9-1-1 lines, may increase the response time as well as provide an opportunity for the introduction of errors into the crash information. The National Mayday Readiness Initiative, a public-private partnership of more than 30 national organizations, co-sponsored by the U.S. Department of Transportation (DOT) and the ComCare Alliance, is attempting to address the issues that arise in dealings between private response centers and PSAPs, including the routing of ACN calls into the 9-1-1 network and the transfer of data messages.

These private response networks will continue to exist at least until a nationwide ACN public response network is deployed, and given the need for public infrastructure development and deployment, that is likely to occur over an extended period. As multiple commercial ACN systems are deployed and an eventual public ACN system developed, there will be a need for compatibility with the public infrastructure and standardization of communications protocols and crash notification messages to allow for interoperability among systems and equipment. In addition, institutional issues such as liability when an ACN does not work as intended or privacy issues associated with ACN data and its collection need to be resolved.

Section 1

INTRODUCTION

1.1 BACKGROUND

In 1998 there were 41,471 fatalities and an estimated 3,192,000 persons injured in police reported motor vehicle traffic crashes (Reference 1). It has been reported that of the approximately 42,000 crash deaths per year, nearly 20,000 die before receiving hospital care and that many of the remaining 22,000 people die after reaching a hospital too late to be saved (Reference 2). In addition, Reference 2 reports that it is estimated that 250,000 of the crash injuries are life threatening and that the economic costs of crash injuries each year amount to an estimated $100 billion dollars. The goal of ACN is to use technology to provide faster and smarter EMS responses in an attempt to save lives and reduce disabilities from injuries. This can be accomplished by both reducing the response time for providing emergency medical assistance to victims of motor vehicle crashes and providing information to improve the response.

To attain this goal, an ACN system should automatically determine that a motor vehicle has been in a collision, notify emergency response personnel of the collision and the vehicle location, provide information concerning the crash, and establish a voice link between the vehicle and emergency response personnel. Information that might be provided about the crash includes estimates of crash severity and the probability of serious injury.

The NHTSA Office of Vehicle Safety Research conducted the ACN FOT to demonstrate the feasibility of fielding an ACN system and the benefits of an ACN system to the victims of motor vehicle crashes. The ACN FOT Program was initiated in October 1995 with the first installations of ACN systems in vehicles starting in July of 1997. While the ultimate measure of benefit of an ACN system is the reduction in the mortality and the morbidity of injuries of crash victims, the focus of the ACN FOT system benefits evaluation was on determining the reduction in EMS response times possible with an ACN system. This emphasis was chosen, as the limited number of crashes expected to occur during the FOT would preclude a meaningful analysis of any reduction in fatalities and injuries.

JHU/APL was selected by NHTSA to be the Independent Evaluator for the ACN FOT. This evaluation report addresses the performance of the ACN system using data collected through the end of the test period in August of 2000. It should be noted that the architecture choice for the ACN FOT and the equipment developed for it were based on what was technologically and financially feasible for this FOT and were not meant to be the choice for future deployed ACN systems. Any attempt to extend the results of this FOT to future ACN system deployments should be undertaken with caution and consideration for the effects of the architecture chosen and the equipment developed for the deployments.

1.2 OPERATIONAL TEST DESCRIPTION

An ACN FOT Team, led by Veridian Engineering (formerly Calspan SRL Corporation), was selected by NHTSA in October 1995 to design, build, install, and conduct the operational testing of an ACN System. The ACN FOT test area, enclosed within the bold black line in Figure 1-1, covered rural and suburban areas of Erie County, New York. In addition to Veridian, the ACN FOT Team included the Erie County Sheriff's Office, the Erie County Department of Emergency Services, Erie County Medical Center (ECMC) Department of Emergency Medicine, Rural Metro Medical Services of Western New York, State University of New York at Buffalo Department of Industrial Engineering, and Cellular One.

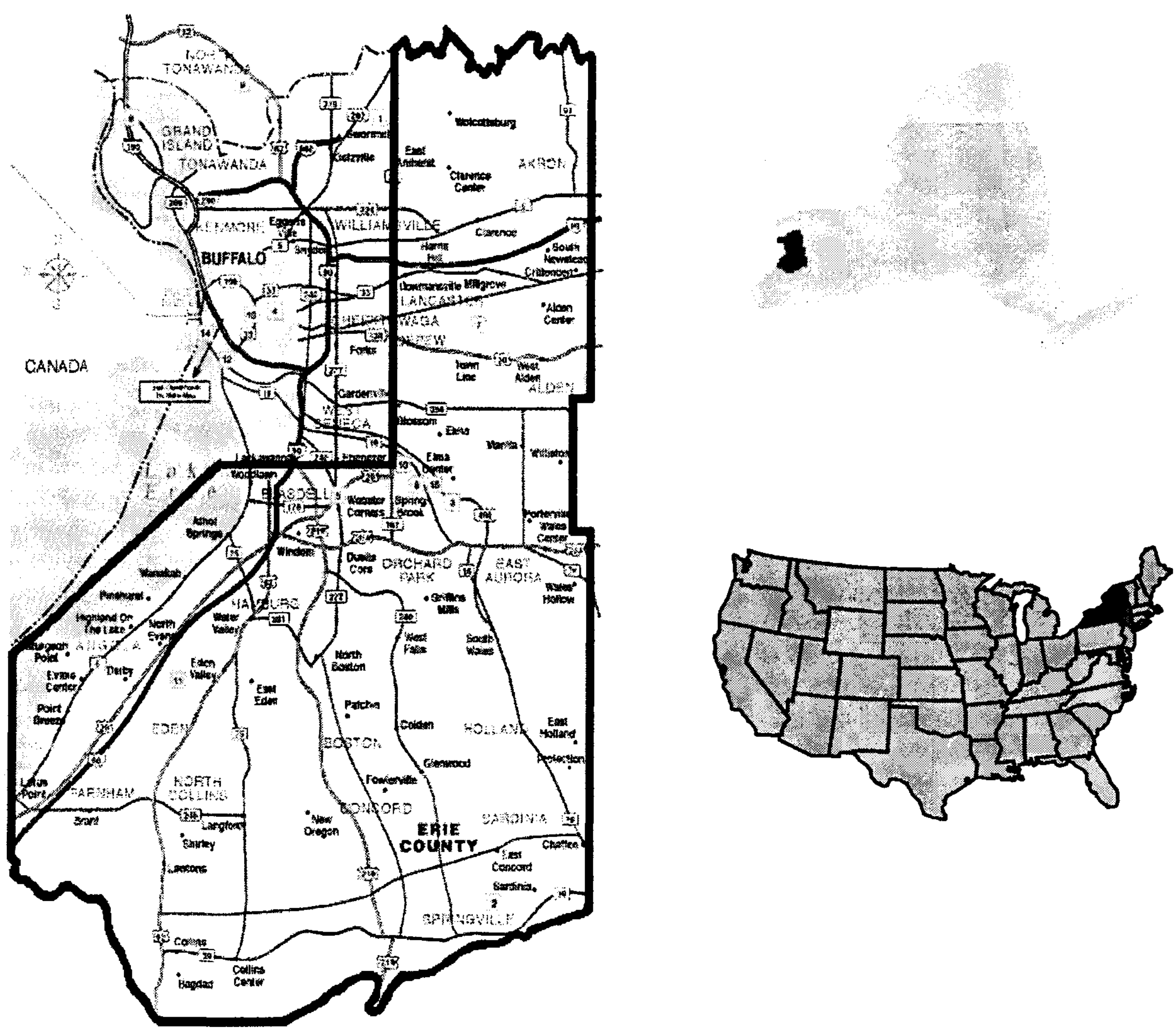

Figure 1-1 ACN FOT Test Area

The FOT included two major data collection efforts. The first collected data on crash notification and emergency medical services response times in Erie County for vehicles without an ACN system, using CETs, providing a baseline against which to judge the performance of the ACN system. The second collected data on crash notification and EMS response times for vehicles equipped with ACN systems. Key dates for the ACN FOT are given in Table 1-1.

Table 1-1 ACN FOT Key Dates

Date	Event
10/95	Start of ACN FOT Program
3/96	CET Design Completed
8/96	First CET Installed
3/97	First Crash of CET-Equipped Vehicle
3/97	Dispatch Facility ACN Equipment Design Completed
4/97	In-Vehicle ACN Equipment Design Completed
6/97	Dispatch Facility Equipment Installed
7/97	First In-Vehicle ACN Equipment Installed
8/97	2500 CETs in Field
2/98	First Crash of ACN-Equipped Vehicle
5/98	15 CET Crashes Available for Analysis
7/98	500 ACN-Equipped Vehicles in Field
4/99	~700 ACN-Equipped Vehicles in Field
8/99	10 Successful ACN Crashes Available for Analysis
8/00	End of Test Period – Data Collection Stops 25 CET Crashes Available for Crash Event Time Analysis 16 Successful ACN Crashes 15 ACN Crashes Available for Crash Event Time Analysis
9/00	End of ACN FOT Program

1.2.1 BASELINE RESPONSE TIME DATA COLLECTION EFFORT

A significant aspect of the ACN FOT was the attempt to collect data that would allow the establishment of a baseline characterization of crash times including notification and EMS response times. While crash times are available from sources such as the Fatality Analysis Reporting System (FARS), there are concerns with the accuracy of currently reported times. FARS, which covers motor vehicle traffic crashes that result in a fatality, reports EMS response times for Time of Crash to EMS Notification, EMS Notification to EMS Arrival, EMS Arrival at Scene to Hospital Arrival, and Time of Crash to Hospital Arrival. These times are derived from Police Accident Reports (PARs), EMS reports, and hospital medical records. A major concern with the accuracy of these response times is that the precise time of crash is often unknown and therefore is based on an estimate in the PAR. In addition, times are often rounded to the nearest multiple of five minutes (Reference 3).

This portion of the ACN FOT involved designing, building, and installing CETs, shown in Figure 1-2, in the vehicles of volunteers from the test area. The CET is a relatively simple and inexpensive device that uses an inertial switch to sense the occurrence of a crash and start a processor counting elapsed time from the start of the event. Veridian, when notified of the crash by either the driver of the CET-instrumented vehicle or law enforcement officials, sent a team to read the elapsed time counter and convert it to the time of the crash. This information was then used with data collected from the PSAPs and EMS service providers to accurately determine the crash notification and EMS response times. CETs were originally to have been installed in 4,000 vehicles for a 1-year test period. However, due to difficulties experienced in recruiting volunteers to have CETs installed in their vehicles, the test period was extended to 4 years (August 1996 through August 2000) with installations occurring during the first half of the test period. About 2,600 vehicles had CETs installed; most of these installations took place between August 1996 and December 1997.

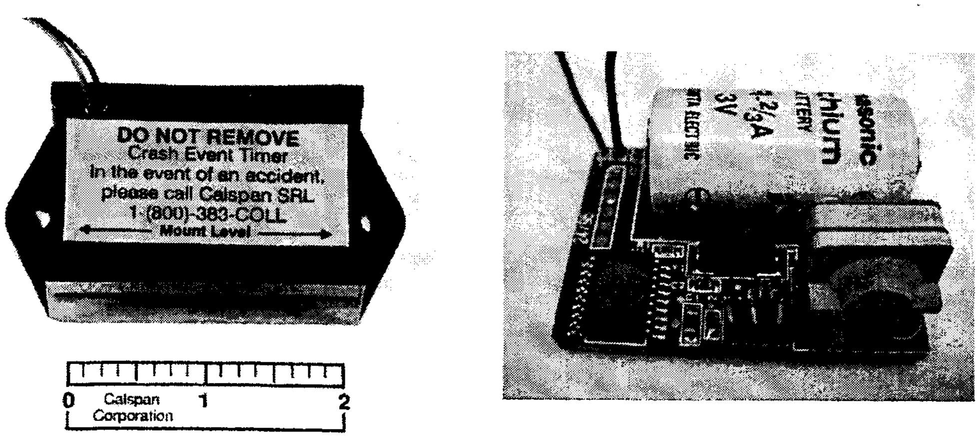

Figure 1-2 Collision Event Timer

1.2.2 ACN DATA COLLECTION EFFORT

The ACN FOT included designing and building ACN in-vehicle systems to automatically detect vehicle crashes and notify 9-1-1 dispatchers about the crash. These systems integrated commercially available accelerometers, cellular communications equipment, and GPS receivers. The in-vehicle system included crash recognition software that analyzed crash forces in real time to determine if thresholds indicating the likelihood of serious injuries were exceeded. A system was also developed to receive and display the ACN notification message at selected PSAPs.

ACN systems were originally to have been installed in 1,000 vehicles for a 1-year test period starting in January 1997. However, due to difficulties experienced in recruiting volunteers and having ACN systems installed in their vehicles, the test period was delayed and extended to a slightly more than 3-year period (July 1997 through August 2000). The goal of installing ACN systems in 1,000 vehicles was not reached. Only about 700 vehicles had ACN systems installed, with installations occurring well into the test period. About 500 systems were installed during the first year of the test period, and the high of slightly under 700 vehicles was reached in April 1999.

Communications, processing, and display hardware and software to receive the ACN crash notification messages were installed at two PSAP locations in Erie County, one at the Erie County Sheriff's Office and one at the ECMC's Medical Emergency Radio System (MERS) dispatch center. As previously stated, information about a crash that might be provided to the emergency response personnel includes an estimate of the probability of serious injury to vehicle occupants. A computer program developed by an NHTSA-sponsored multidisciplinary research team that produces such estimates (References 2, 4, and 5) was installed in the dispatch facility ACN equipment. Further details of the in-vehicle and dispatch facility equipment, the probability of serious injury algorithm, and the operation of the Veridian system are given in Section 2 of this report.

The ACN data collection effort supported the evaluation of ACN system performance. Data were collected automatically from the ACN system and the dispatch center and manually from the PSAPs and EMS service providers. In addition, experienced crash investigation teams from Veridian reviewed all crashes involving ACN-equipped vehicles, inspecting all involved vehicles and the crash scene; interviewed police, EMS dispatchers, and fire/rescue personnel; collected notification and response times of emergency services; analyzed dispatcher emergency message records; and obtained injured victim medical records.

1.2.3 ACN FOT EVALUATION

The independent evaluation of the ACN FOT included the participation of the ACN FOT Team. The ACN FOT Team led by Veridian worked cooperatively with the Independent Evaluator (JHU/APL), and was jointly responsible for the required data collection and data analysis activities. The plan for the independent evaluation of the ACN FOT was described in a series of three reports. An Evaluation Plan (Reference 6) described the specific goals and objectives of the independent evaluation and identified the measures of effectiveness, performance, and suitability to be used in the evaluation. The Data Collection Plan (Reference 7) identified the data elements to be collected and the approaches to collecting that data. And the Data Analysis Plan (Reference 8) described the data reduction and analysis methods to be used to translate the collected data into the measures of effectiveness, performance, and suitability.

The evaluation goals were to

a. Evaluate System Benefits

b. Evaluate System Performance

c. Evaluate Institutional Issues

d. Evaluate User Acceptance

e. Evaluate System Costs.

As previously stated, the evaluation of system benefits focused on determining the reduction in EMS response times possible with an ACN system. The response times that were measured and analyzed are identified and discussed in Section 3 of this report. The evaluation of system performance measured the notification time, notification failure rate, and false notification rate for the ACN system. In addition, the accuracy, availability, reliability, and survivability of the ACN system and its components were evaluated. These measures of performance are discussed in Section 4 of this report.

The objective of the evaluation of institutional issues was to document those institutional and legal issues that were encountered during the ACN FOT, along with their resolution and recommendations concerning them. Issues documented covered both the deployment of an ACN system and the conduct of the FOT. The evaluation of user acceptance concentrated on determining users' impressions of the effectiveness of the ACN system and their identification of features that were desirable or necessary for an ACN system. The goal of the evaluation of system costs was to document the costs associated with building and operating the ACN system used in the FOT. No attempt was made to estimate the costs associated with the large-scale deployment of an ACN system.

1.3 ORGANIZATION OF DOCUMENT

The purpose of this ACN FOT Evaluation Report is to assess the performance of the ACN FOT using data collected through the end of the test period in August 2000. This document is divided into an executive summary and seven sections. Following this introductory section, Section 2 describes the architecture of ACN systems both in general and as used in the ACN FOT. Section 3 presents an evaluation of ACN system performance covering the areas of response times, system failures and false notifications, message and position accuracy, and system reliability, survivability, and availability. Section 4 evaluates user acceptance of the ACN system and reports on the costs of developing and producing the ACN system used in the FOT. Section 5 discusses the institutional issues encountered during the FOT and their resolutions. Section 6 discusses estimates of the societal benefits of introducing ACN systems. Finally, Section 7 presents summary observations from the evaluation of the FOT.

Section 2

ACN SYSTEM ARCHITECTURE

2.1 INTRODUCTION

This section describes possible ACN system architectures to enable a better understanding the ACN FOT evaluation results. The discussions of possible ACN in-vehicle systems and the response networks to receive the crash notification messages are followed with descriptions of the systems used for the ACN FOT. As previously noted, the purpose of an ACN system is to automatically determine that a collision has taken place, notify emergency response personnel of the collision and the vehicle location, provide information concerning the crash, and establish a voice link between the vehicle and emergency response personnel. Information that might be provided about the crash includes estimates of crash severity and the probability of serious injury. Crash severity estimates may be based on crash data, such as the change in velocity during the crash, the principal direction of force, and/or whether the vehicle was in a rollover. Estimates of the probability of serious injury may be based on the crash severity information along with vehicle data (e.g., vehicle weight, presence or absence of fire, or air bag deployment) and occupant-related information (e.g., age, gender, or safety belt use). An example ACN system is shown in Figure 2-1. The goal of such a system is to improve victim care following a crash by reducing the response time for providing medical assistance and increasing the information available for appropriate triage, transport, and treatment decisions.

The example ACN system may be viewed as consisting of an In-Vehicle System and a Response Network. The In-Vehicle System contains a crash sensor to determine that a collision has taken place, a location system to determine the position of the vehicle, and a wireless communications system to send the crash notification to the appropriate PSAP for emergency response dispatch. The Response Network may be thought of as the collection of systems used to deliver the crash notification message and generate an EMS response. It may include the use of a private response center that forwards the crash data and voice connection to the appropriate PSAP based on the vehicle location.

2.2 ACN IN-VEHICLE SYSTEM

The ACN In-Vehicle System should determine that a crash has taken place, identify the location of the vehicle, support the determination of crash severity and probability of serious injury, and communicate with an emergency response center. This corresponds to an architecture, shown in Figure 2-2, that carries out the following four functions:

a. Location Determination

b. Collision Sensing

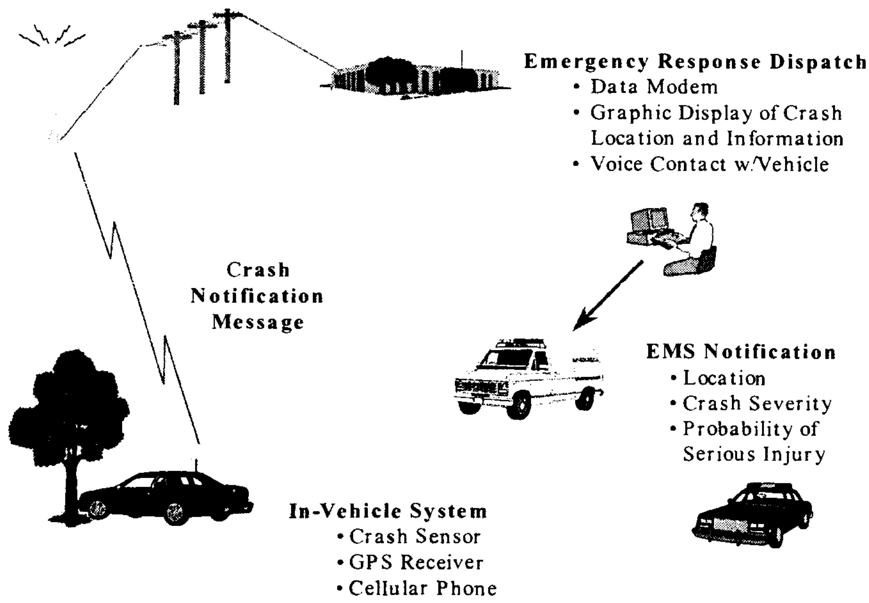

Figure 2-1 Example ACN System

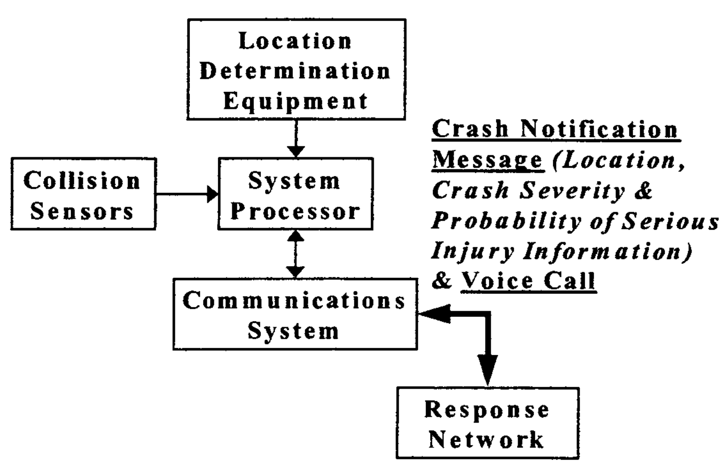

Figure 2-2 In-Vehicle System Architecture

c. System Processing - includes determining that a reportable crash has occurred, support of crash severity and probability of serious injury estimation, and producing the crash notification message

d. Wireless Communications.

The primary method being considered by ACN systems for location determination is the use of GPS receivers. GPS provides two levels of location determination. The GPS Precise Positioning Service (PPS) is restricted to U.S. Armed Forces, U.S. Federal agencies, and selected allied armed forces and governments, while the GPS Standard Positioning Service (SPS) is available to all users. The PPS provides location accuracy to 22 m 95 percent of the time. Prior to 2 May 2000, the SPS was intentionally degraded to provide location accuracy to 100 m 95 percent of the time. Since 2 May 2000, degradation of SPS has ceased and the accuracy of SPS approaches that of the PPS. It has been reported on the U.S. Government Interagency GPS Executive Board Worldwide Web Site that users of SPS can expect a predicted error of approximately 20 m. In addition, GPS accuracy can be increased by the use of differential correction data from Government or private services to 10 m or better. The U.S. Coast Guard is currently leading the implementation of a National Differential GPS system that will provide 1- to 3-m accuracy with complete coverage of the U.S. by 2003.

An alternative method of location determination would be to use the location information to be provided for wireless 9-1-1 calls by wireless service providers upon the implementation of the Federal Communications Commission (FCC) Rules for Enhanced 9-1-1 (E9-1-1) for Wireless Services (References 9, 10, and 11). While E9-1-1 for wireline telephones automatically provides a caller's name, address, and phone number to the 9-1-1 operator, currently when a 9-1-1 call is placed using a wireless telephone, the dispatcher at the 9-1-1 PSAP does not know where the caller is. Wireless telephones will implement E9-1-1 in two phases. The first phase requires wireless carriers to provide the 9-1-1 operator with a dialable callback number for the cellular telephone and the location of the base station or cell site receiving the 9-1-1 call. Phase I service was to have been implemented by April 1998 for those PSAPs requesting it, however as of April 2000 Phase I service has not been widely implemented. The second phase requires in addition that a more precise location identification, given in Table 2-1, be provided using either network-based or handset-based location methods. The wireless carriers are required to report the method they will use for Phase II location determination by October 2000. Implementation of this service for those PSAPs requesting it is to occur by October 2001, although for handset-based implementations full conversion is not required before December 2004.

Table 2-1 FCC Phase II Location Standards

Location Method	Accuracy Reliability 67 % of Calls	95 % of Calls
Network-based	100 m	300 m
Handset-based	50 m	150 m

The purpose of the collision sensors is to collect information that both allows the system to detect the occurrence of a crash and to support the determination of crash severity and the probability of serious injury. It has been recommended (Reference 12) that accelerometers be used to detect crashes in ACN systems due to their ability to completely characterize the forces in a crash. Instead of the use of accelerometers dedicated to the ACN function, some ACN systems are basing collision sensing on activation of air bag deployment. It should be noted that the use of air bag deployment for crash determination results in an under-reporting of non-frontal crashes (rear, side, and rollover) that may require emergency responses.

The system processing function controls the operation of the ACN system. It processes the collision sensor data to determine if a crash has occurred, assembles the crash notification message, which includes the vehicle location and crash severity and probability of serious injury information, and operates the communications system. The determination of crash occurrence involves comparing the severity of the crash to a threshold. This threshold should be set to minimize notifications when EMS response is not needed, in order to avoid overloading the emergency response system. It should be noted that the setting of this threshold will involve a tradeoff between the expectations of the driving public and the law enforcement and EMS community. It is believed that the driving public expects to see the majority of crashes reported, while the law enforcement and EMS community would like to minimize the number of non-injury, low-damage crashes that are automatically reported. ACN systems should also provide a backup manual-activation capability.

The current communications system choice for ACN systems has been the use of a cellular phone; cost and service concerns have kept other communications systems (e.g., satellite communications systems) from being seriously considered at this time. This limits the functionality of an ACN system to areas where there is cellular phone coverage. While cellular coverage is not universal, it is good and is expanding. For example, the number of commercial cell sites has gone from 22,663 in December 1995 to 81,698 in December 1999, an increase of 360 percent (Reference 13).

Figure 2-3 shows the in-vehicle equipment suite used by Veridian for the ACN FOT. It may be considered representative of an in-vehicle system that determines location using GPS and senses a crash with accelerometers dedicated to the ACN function. This in-vehicle system consists of a Veridian developed In-Vehicle Module (IVM), a cellular phone handset, a 3-watt cellular phone transceiver, a cellular phone antenna, a GPS antenna, and a back-up battery for the ACN equipment.

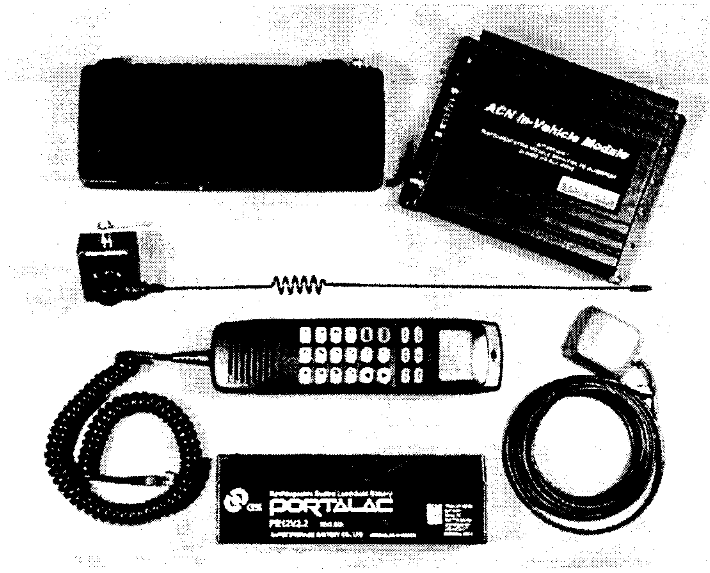

Figure 2-3 Veridian ACN In-Vehicle Equipment Suite

The IVM is the key element of this suite and is generally installed in areas not likely to be impacted by a crash (e.g., under the rear seat). It contains a high performance 16-bit digital signal processor, three orthogonally mounted micro-machined accelerometers, a single-chip modem, a Rockwell Jupiter 12-channel GPS unit, power conditioning circuitry, and 128 kbytes of non-volatile flash memory to store detailed crash event histories. The cellular phone data modem employs a Frequency Shift Key V.23 data transfer format protocol.

The IVM signal processor continuously monitors the outputs of the three accelerometers to detect the occurrence of a crash using an algorithm that computes a measure of the severity of the crash based on the vehicle acceleration history prior to and during the crash. This output is compared to a threshold based on an estimate of injury risk being exceeded to determine the occurrence of a crash. The ACN FOT variable threshold is a function of the change in velocity and principal direction of force for the crash.

Once a crash is detected, the signal processor assembles a data message containing the vehicle location, information characterizing the crash (e.g., change in velocity, principal direction of force, and rollover occurrence), and the vehicle cellular phone number. The signal processor then uses the vehicle cellular phone to deliver the crash notification message. Once the data message is delivered, the system automatically switches to voice mode providing the vehicle occupants with a hands-free voice line.

2.3 RESPONSE NETWORK

The Response Network's function in an ACN system is to receive the crash notification message, extract the vehicle location and any other crash information that might affect the provision of EMS, and to dispatch the appropriate EMS response. The EMS response may be based on estimates of the severity of the crash or the probability of serious injury generated from the information in the crash notification message and supplemental information gathered via the voice link with the vehicle occupants or from vehicular databases.

Two response network architectures have been considered for deployment – private and public. It is the choice of the number and organization that is called that differentiates the two architectures. Private response networks are available to subscribers, for a fee, and are typically reached by dialing a 1-800 number. The ACN call is answered by a commercial response center, which forwards the call to the appropriate PSAP for EMS dispatch based on the vehicle's location. Public response networks are envisioned as being available to all callers. The ACN system would dial the national emergency number 9-1-1 for automatic connection to the appropriate PSAP. The ACN FOT response network, which is described below, was a hybrid architecture containing features of both the private and public network architectures. It was based on what was technologically feasible and financially affordable for the FOT and was not meant to be the architecture choice for future deployed ACN systems.

2.3.1 PRIVATE NETWORK

An example private or commercial response network architecture is shown in Figure 2-4. In this architecture the In-Vehicle System generates a 1-800 number call to the national or regional message center to which the vehicle subscribes. This call transfers both the crash notification data message and a voice connection to the vehicle. The crash data are displayed to a response center operator who confirms the emergency via the voice connection. The response center then contacts the appropriate PSAP using the "pseudo number" for the PSAP, which is obtained from a database using the vehicle location. The "pseudo number" is a dialable number that the PSAP receives as a 9-1-1 call from an unknown address in its service area. The operator informs the PSAP dispatcher of the nature of the emergency, the location of the vehicle, provides any other useful information contained in the collision notification message, and connects the voice call to the PSAP.

It should be noted that currently calls between private response centers and PSAPs are often made using administrative phone numbers for the PSAPs (non-9-1-1 lines), rather than by the use of "pseudo numbers." This may result in delays in the delivery of a crash notification message. The National Mayday Readiness Initiative, a public-private partnership of more than thirty national organizations, co-sponsored by the U.S. Department of Transportation (DOT) and the ComCare Alliance, is attempting to address the issues, including the routing of ACN calls into the 9-1-1 network, that arise in dealings between private response centers and PSAPs.

Commercial crash notification services were first offered in 1996 and typically base notification on air bag deployment or manual activation and location determination on GPS. While these systems do not perform all the functions of ACN systems as previously described (e.g., automatic notification for all types of crashes or support of crash severity and probability of serious injury estimates); they may be viewed as a first step in the deployment of such systems. Example systems are the OnStar service provided by GM and the services provided by ATX Technologies, formerly Protection One, for Ford, Lincoln-Mercury, Jaguar, Mercedes-Benz, and Infiniti. The OnStar service as of late 1999 had been installed on over 75,000 vehicles and was standard on some Cadillacs and available as an option on many other GM models. These commercial ACN services are typically bundled with other services such as roadside assistance, remote door unlock, stolen vehicle tracking, routing assistance, remote diagnostics, and concierge services. While these systems are not currently able to provide data messages to the PSAPs, it is possible that this capability could be implemented in the future. However, standards would need to be developed for the transfer of data between commercial message centers and PSAPs to support efficient operation with multiple commercial crash notification services.

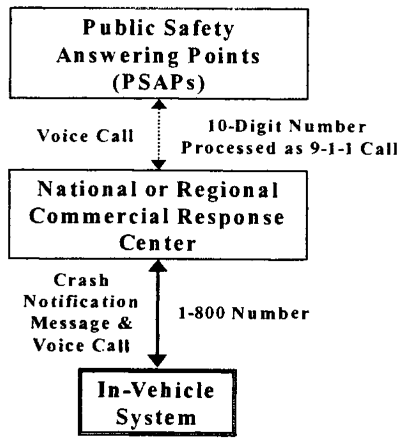

Figure 2-4 Private Response Network Architecture

Positive aspects of the private network type of architecture include the facts that they are currently available and do not require modifications to the public emergency response infrastructure to receive ACN calls. Modifications to response center dispatch equipment to receive data calls and display the crash information are limited to the commercial response center. Current negative aspects of this type of architecture are that it is not a universal service and the use of only voice lines to connect the commercial response centers to the PSAPs. The concern with it not being a universal service is that the ability to use this safety service would be dependent on maintaining a paid subscription to a commercial service and an active cellular phone account (due to not dialing 9-1-1 for the call). While the use of voice lines to connect to the PSAPs allows for the possibility of error or misunderstanding in the communication of the crash data.

In addition, these systems must maintain an up-to-date database of PSAPs, their service areas, and their "pseudo numbers." Possible problems with the determination of which PSAP to call include changing PSAP boundary lines that may not be reflected in the available databases and overlap in jurisdiction among PSAPs. For example, in some areas the State Police or Patrol provide law enforcement on state and interstate highways while the local Sheriff or Police are responsible for calls on county, town, or city roads.

2.3.2 PUBLIC NETWORK

Two examples of a public response network architecture are shown in Figure 2-5. In the primary architecture, the In-Vehicle System generates a 9-1-1 call that is routed automatically to the PSAP with responsibility for the vehicle's location. This call transfers both the crash notification data message and a voice connection to the vehicle, with the message data automatically displayed to the PSAP operator. The routing of the call to the correct PSAP is based on the wireless 9-1-1 network's determination of the vehicle location, although the position determination by the ACN In-Vehicle System would still be available in the crash notification message.

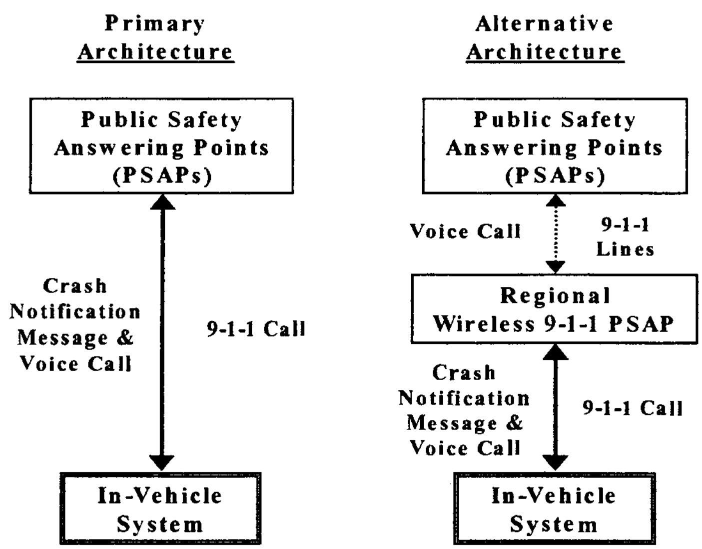

Figure 2-5 Public Response Network Architectures

The alternative architecture, shown in Figure 2-5, is meant to be representative of situations where either the wireless 9-1-1 network cannot determine the vehicle's location or where there is an inability or desire not to upgrade all PSAPs to handle the ACN crash notification message. In this architecture a regional wireless 9-1-1 PSAP receives the call and displays the crash information to the operator. The regional PSAP operator confirms the emergency via the voice connection. The regional PSAP then contacts the appropriate PSAP via a 9-1-1 line, and informs the local PSAP dispatcher of the nature of the emergency and the location of the vehicle, provides any other useful information contained in the collision notification message, and connects the voice call to the local PSAP.

The primary positive aspect of the public network type of architecture is that it would be universally available to any vehicle that had an in-vehicle ACN system without the need to pay a fee to maintain the service. It should be noted that 9-1-1 calls can be made on a cellular phone that does not have an active service agreement. Other positive aspects are that it uses the national emergency number 9-1-1 and connects directly to the same emergency response professionals that run the 9-1-1 system, which may result in a reduction in EMS notification time.

The foremost negative aspect of this type of architecture is that it does not currently exist and may require modifications to the public emergency response infrastructure to receive and display ACN calls. The need to make modifications to response center dispatch equipment will likely delay the introduction of this type of architecture. It should be noted that even though 9-1-1 service was introduced in 1968 not all of the United States currently has 9-1-1 service. The National Emergency Number Association reports that currently nearly 93% of the population of the United States is covered by some type of 9-1-1 service, with 95% of that coverage being Enhanced 9-1-1, which automatically provides a caller's name, address, and phone number to the 9-1-1 operator. Approximately 50% of the geographic United States is covered by some type of 9-1-1. The alternative public network architecture is meant to encourage the adoption and use of ACN systems by limiting the need to modify the public emergency response infrastructure to designated regional wireless 9-1-1 PSAPs.

It should be noted that an important requirement for the successful implementation and deployment of a public response network architecture is the availability of standards defining the means of delivering the crash notification data message from the in-vehicle system to the PSAP. Possible methods of delivering the data message may include dividing the data portion of the call from the 9-1-1 voice call for separate delivery, either directly to the PSAP or indirectly via insertion into a database that can be accessed by the PSAP or other emergency response agency. These standards should cover both the formats of the crash notification message and the protocols used for transferring the message.

2.3.3 ACN FOT NETWORK

The ACN FOT response network was a hybrid architecture containing features of both the private and public network architectures. While crash notification calls were made via a 1-800 number to a single regional message center for the Erie County area, that center was an operational PSAP. The architecture choice for the ACN FOT was based on what was technologically feasible and financially affordable for this FOT and a desire to avoid changes to the emergency response system during this technology demonstration. It was not meant to be the architecture choice for future deployed ACN systems.

Upon detection of a crash, the ACN FOT In-Vehicle System assembled the crash notification message and used the vehicle cellular phone to automatically dial a programmed 1-800 number that rings at the 9-1-1 Dispatch Center located at the Erie County Sheriff's Office. It then transmitted a data message with the crash information and received confirmation from the ACN FOT dispatch center equipment that the message was received. At the 9-1-1 Dispatch Center, a computer console displayed a detailed road map with the vehicle's last location, along with a series of past locations, as well as data characterizing the crash. The displayed data included the change in velocity experienced by the vehicle; whether the crash was a frontal, side, or rear impact crash; whether a rollover occurred, the make, model, and year of the vehicle; and the probable occupants of the vehicle. This computer console, supplied by Veridian, was a PC-based system that integrated commercial off-the-shelf hardware and software with software developed for the ACN FOT that allowed ACN message reception and display. An example of the dispatch center display screen is shown in Figure 2-6.

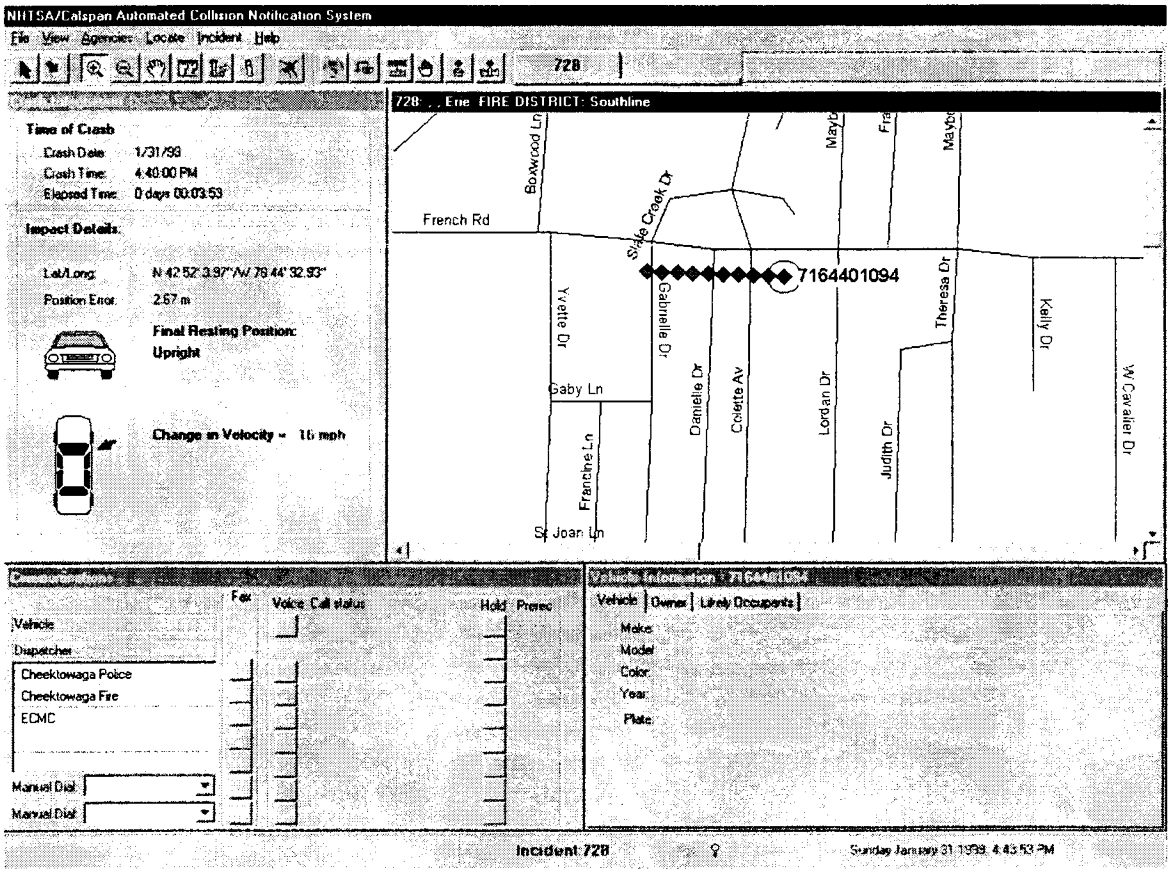

Figure 2-6 Dispatch Center Display Screen

Once the data message was concluded (approximately 15 seconds to a minute to establish the cellular connection and 5 to 10 seconds to transmit the data message), the system automatically converted to a hands-free voice line to the vehicle occupants. The Sheriff's Office dispatcher had the opportunity to confirm the nature of the emergency and obtain additional information (e.g., number of cars and occupants involved in the crash and confirmation of the crash location). The Sheriff's Office then alerted the appropriate PSAP of the emergency by a voice call and could also send the PSAP a fax of the dispatch center display. The voice call from the vehicle could also be forwarded. The PSAP then dispatched the appropriate emergency service providers to the scene. The data message was also displayed on a computer console at the ECMC 9-1-1 medical dispatch center and the Sheriff's Office could conference the ECMC personnel in on the voice line to the vehicle. The ECMC personnel could then provide medical instructions to the vehicle occupants prior to the emergency service provider arrival at the scene.

It is desirable to determine an appropriate EMS response based on estimates of the probability of serious injury or the severity of the crash. However, it also desirable to avoid overloading PSAP dispatchers with information they cannot understand to support the making of these decisions. The URGENCY computer program developed by an NHTSA-sponsored multidisciplinary research team (References 2, 4, and 5) was installed in the dispatch facility ACN equipment to produce an easily understood probability of serious injury estimate. The URGENCY software used the information provided in the crash notification message (i.e., change in velocity (Crash Delta V), principal direction of force, whether the vehicle was in a rollover) along with supplemental information obtained from vehicle databases or from the vehicle occupants (e.g., occupant age and gender, use of seatbelts, vehicle weight and damage) to automatically calculate the probability of serious injury for the crash. Figure 2-7 shows an URGENCY rating of an 89% probability of the presence of at least one serious injury (Abbreviated Injury Scale (AIS) 3 or greater rating). In this example, the 89% URGENCY rating was triggered by a side impact crash with a 38-mph change in velocity involving a rollover with a 30-year old female occupant.

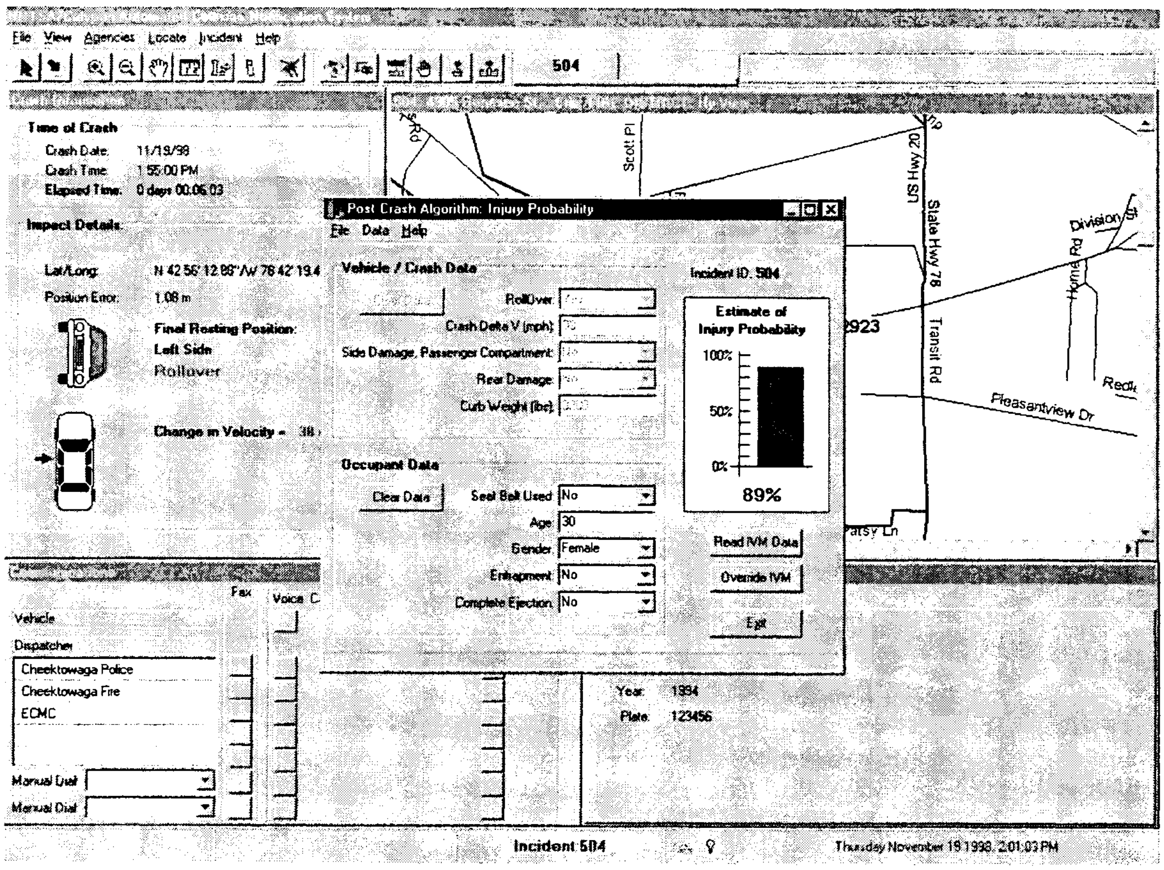

Figure 2-7 Dispatch Center Injury Probability Display Screen

During the ACN FOT this display was available, but not automatically shown to the dispatcher; instead, the operation of the algorithm was investigated after the crash. The developers of the URGENCY software envision that future versions of the software could include other sensor data, such as crash pulse, airbag time and level of deployment, seat belt forces, door openings, presence or absence of fire, and the number, size, and seating positions of occupants to further improve EMS response.

2.3.4 FUTURE RESPONSE NETWORK ARCHITECTURE

While the above paragraphs have discussed the development of the response network architecture in terms of it being either a private or public system, it is likely that the future response network architecture will be a combination of both the private and public architectures. In the absence of an ACN public response network, the first commercial crash notification services have already deployed their versions of private response network architectures. These will continue to exist at least until a nationwide ACN public response network is deployed, which is likely to occur over a period of years.

It should be noted that as multiple commercial ACN systems and an eventual public ACN system are deployed, there will be a need for a standardization of methods, protocols, and messages to allow for interoperability between systems and equipment. Work has already started in this area. The Society of Automotive Engineers (SAE) has issued an On-Board Land Vehicle Mayday Reporting Interface Standard (J2313) for vehicle to response center messages. Also, the Institute of Electrical and Electronics Engineers (IEEE) Incident Management Working Group is working on a standard for message sets for incident management that covers messages between the Emergency Management Center, Traffic Management Center, and Emergency Telephone Systems.

Section 3

EVALUATION OF ACN SYSTEM PERFORMANCE

3.1 INTRODUCTION

The objectives identified in Reference 6 for evaluating system performance and benefits in the ACN FOT are reproduced in Table 3-1. This section describes the collection and reduction of the FOT data to produce quantitative results for the Measures of Effectiveness (MOEs) and Measures of Performance (MOPs) that categorize these objectives. The test objectives and their associated measures are divided into the following six groupings:

a. Crash Event Times

b. Notification Performance

c. Accuracy

d. Reliability

e. Survivability

f. Availability.

The following paragraphs will cover the data collection process for these MOEs and MOPs, and the results obtained for the six performance groupings.

3.2 SYSTEM PERFORMANCE DATA COLLECTION

The system performance data elements to be collected and the approaches to collecting the data were identified in Reference 7. System performance data were primarily collected from crashes of ACN- and CET-equipped vehicles. The relevant crash data elements were mainly times which reflected the response of the various parts of the emergency response system (police, fire, ambulance), as well as post-crash reconstruction of the kinematic sequence of events by a qualified crash investigator, in order to estimate the accuracy of the ACN information. Information concerning the reliability, survivability, and availability of the ACN system was collected throughout the FOT.

This section will briefly describe the various types of data collected during the FOT for the purpose of evaluating system performance, namely response time and crash reconstruction data. In addition, subsection 3.2.3 will discuss the size of the data sample and its statistical validity.

Table 3-1 ACN Field Operational Test System Evaluation Objectives

ACN FOT Goal	No.	Objective
Evaluate System Benefits	1.1	Measure the change in PSAP Notification Time due to the ACN system
	1.2	Measure the change in EMS Notification Time due to the ACN system
	1.3	Measure the change in EMS Response Time due to the ACN system
	1.4	Measure the change in Dispatch Time due to the ACN system
	1.5	Measure the change in EMS Travel Time due to the ACN system
	1.6	Measure the change in EMS Delivery Time due to the ACN system
Evaluate System Performance	2.1	Measure the notification failure rate for the ACN System
	2.2	Measure the false notification rate for the ACN System
	2.3	Measure the Central Dispatch Notification Time
	2.4	Assess ability of the Central Dispatch Facility personnel to dispatch EMS equipment based on the information provided by crash notification message
	2.5	Determine the accuracy of the delivered crash notification message
	2.6	Measure the position location component accuracy
	2.7	Measure the reliability of the in-vehicle system
	2.8	Measure the crash sensor component reliability
	2.9	Measure the position location component reliability
	2.10	Measure communications component reliability
	2.11	Evaluate central processor reliability
	2.12	Determine reliability of the CDF equipment
	2.13	Measure the survivability of the in-vehicle system
	2.14	Measure the position location component survivability
	2.15	Measure communications component survivability
	2.16	Evaluate central processor survivability
	2.17	Measure communications availability
	2.18	Measure the position location component availability
	2.19	Evaluate the ability of the EMS dispatcher to talk directly to individuals involved in a crash

3.2.1 RESPONSE TIME DATA

EMS notification and response times are calculated from event times recorded during crashes. A typical ACN crash event timeline (with times rounded to the nearest minute) is shown in Figure 3-1, providing an indication of the types of crash event times collected. A CET crash would have a similar timeline, except there would be no automatic notification at the Erie County Sheriff's Office Central Dispatch Facility (CDF).

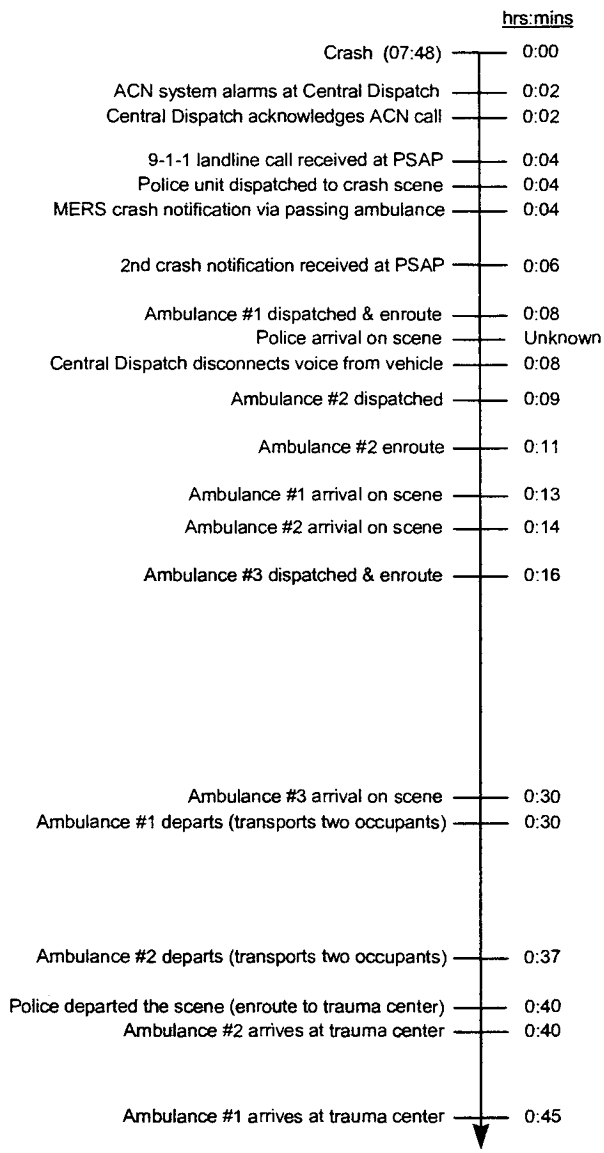

Figure 3-1 Representative ACN Crash Event Timeline

For the ACN FOT, the primary EMS Response Times were defined as follows:

a. Central Dispatch Notification Time - period from occurrence of crash until the CDF is notified of crash by ACN System

b. PSAP Notification Time - period from occurrence of crash until appropriate PSAP is notified by the CDF (or by any means for CET crashes)

c. EMS Notification Time - period from occurrence of crash until appropriate EMS provider is notified by PSAP

d. EMS Response Time - period from occurrence of crash until the first EMS unit arrives at the crash site

e. Dispatch Time - period from PSAP notification of crash until EMS unit is dispatched to crash

f. EMS Travel Time - period from EMS unit dispatch until arrival at crash site

g. EMS Delivery Time - period from first notification of the crash until EMS unit arrival at Emergency Care Facility.

Veridian was responsible for collecting all relevant times for each crash during the FOT. The times recorded included notification times for the various emergency response agencies and, where appropriate, their dispatch times, arrival and departure times at the scene of the crash, and arrival time at the emergency care facility. In the event of multiple emergency response vehicles (e.g., two or more ambulances), separate time sequences were recorded and maintained. While GPS derived time was the baseline time for all time measurements, many of the crash event times were manually obtained from a number of sources at different locations. In order to achieve the accuracy levels specified for the FOT (primarily one-minute, as described in Reference 7) and minimize systematic bias, a careful synchronization process was necessary to align all of the time sources to the GPS baseline time. In other words, each of the clocks at the various locations had to be adjusted to the same reference time.

For the ACN-equipped vehicles, the crash occurrence time was available from the delivered crash notification message at the central dispatch facility or from the in-vehicle system. This time is directly referenced to GPS time. For crashes involving the CET-equipped vehicles, the time was calculated from the CET timer, which measures elapsed time since the crash in 2-second intervals. A GPS-based time standard was used for converting the elapsed time to the crash occurrence time.

3.2.2 CRASH RECONSTRUCTION DATA

A crash investigation was performed for each reported collision involving a registered test vehicle. A crash investigator examined the crash scene, vehicle, and the in-vehicle system (ACN or CET). Police reports and the voice recordings from the Erie County Sheriff's Office CDF, the MERS at the ECMC, and the PSAPs were reviewed. Finally, interviews were conducted with the driver (and passengers, if appropriate and available), EMS providers, responding police officers, Erie County Sheriff's Office CDF personnel, MERS personnel, and medical personnel. These investigations were similar to those done for the NHTSA's National Automotive Sampling System (NASS) crash investigations, but not to the same level of detail.

A number of aspects of the crash were considered and recorded during this portion of the FOT. These included the source of the initial notification; determination of whether a crash actually occurred; crash particulars (e.g., vehicle damage or occupant injuries); and, if applicable, ACN system performance (e.g., delivery of crash notification message, establishment of voice communications, etc.). Clearly, not all of this information was necessary if it was determined that the incident was not a crash event. CET events did not require the recording of ACN information.

3.2.3 OPERATIONAL TEST DATA SAMPLE

This section describes the data collection effort associated with the CET- and ACN-equipped vehicles. In particular, the size of the data sample is discussed, as well as some of the effects on the data due to difficulties encountered in operational testing.

3.2.3.1 CET Data

The first CETs were installed in vehicles in the fall of 1996 and around 2600 are known to have been installed during the FOT. Assuming they all remained in service as of 31 August 2000, there have been nearly 3 million CET days in the field. The original goal for the FOT was around 1.5 million days in the field (4,000 units for one year). Therefore, under the foregoing assumption, the time exposure of CETs exceeded the pre-FOT expectations. This was mainly due to the fact that difficulties with production, recruitment, and installation of ACN in-vehicle systems caused the test period to be extended from the originally proposed 1-year term. The validity of the assumption that all of the CET-equipped vehicles remained in service is discussed below.

The CET was not designed to collect time of crash data for crashes expected to produce only minor property damage. This was done by allowing the CET to trigger only if the crash met certain impact requirements, in effect imposing a minimum crash threshold. A total of 76 CET crashes were reported to Veridian during the FOT. Thirty-six of these reported crashes were above the minimum crash threshold, while forty were below the minimum crash threshold and thus did not have any time of crash data available. However, 11 of the 36 above-threshold CET crashes also did not have time of crash data available due to notification failures or delays, leaving only 25 CET crashes available for analysis.

Considering the field exposure cited above, the number of CET crashes, both above or below the minimum crash threshold, was far below that which would be expected for the number of CETs installed. This discrepancy between expected and observed crash rates may be partially explained by the results of a random survey conducted by Veridian (Reference 14) in the fall of 1999. Of 46 CET participants contacted by Veridian, only 31 still owned the vehicle originally registered for the FOT. This suggests the possibility that around one-third of the CET vehicles were no longer participating in the test. In addition, while seven of the participants surveyed indicated that they were involved in crashes during the test period, only four of the seven had reported the crash to Veridian.

While this data sample was admittedly small, it indicates that a significant fraction of CET participants might not have complied with the procedures outlined for participation in the FOT; and provides evidence that a significant percentage of the original test vehicles were not involved in the FOT for the entire test period and that a substantial fraction of the test participants might not have reported crashes which occurred. Additionally, while not addressed in this cursory analysis, there is also the possibility that a sizeable number of participants may have left the test area, as Veridian experienced difficulty in contacting many of the participants.

Using the results of this survey, along with some conservative simplifying assumptions about the installation of the CETs and the rate at which participants removed cars from the test, one may reassess CET exposure during the FOT. It should be noted that the simplifying assumptions mentioned are consistent with all of the information available from the survey and the database. Using these techniques, the number of CET days in the field drops to around 2.3 million, and the number of CET vehicles remaining in service at the end of the test period is estimated to be around 1450, with the number decreasing by around 1.5 % each month.

For an exposure of 2.3 million days, one would expect to observe between 180 and 540 total crashes (depending on the average number of miles driven per year), of which around one-third, or 60 to 180, would involve injuries, with the rest involving mainly property damage (Reference 15). In an attempt to determine whether crashes of CET vehicles were occurring at the expected rate, but simply not being reported, Veridian in September 1999 sent a list of all of the CET participant license plate numbers to the New York Department of Motor Vehicles (DMV). They requested that the DMV check for police-reported crashes involving those vehicles since the start of the FOT. The result of this check was that 100 crashes involving CET participants were found to have been reported to the police during the test period, with 58 of these involving personal injuries (Reference 14). The discrepancy between the fraction of personal injury crashes observed in New York State (58%) and that expected (33%) might have been due to the limitation on New York State Police reporting of property-only crashes to those above $1000.

A simplified probability analysis of the Veridian and DMV data yielded the result that the average probability of a CET crash being included in the Veridian database during the test period was 0.26 or 26 percent (not all of the Veridian crashes were included in the DMV data and not all of the DMV crashes were include in the Veridian database). The test database included a total of 76 in-area CET crashes (both below and above the reporting threshold), of which 36 were determined to be above threshold. This means that the CET test population probably experienced around 290 crashes, of which around 96 would be expected to involve injuries. Due to problems with participant reporting rates, the test data included only around a quarter of these. Note that the DMV data, although more complete than the test data, are also probably missing more than 40 percent of the crashes. Again, it is expected the DMV database would not include all crashes, since many property damage crashes have been deliberately excluded. If the same probability analysis is performed on the sample of injury crashes only, then the probability of an injury crash appearing in the Veridian database is 0.16, while that for the DMV database rises to 0.69. The expected total number of injury crashes is then calculated to be around 100. Given the large uncertainties associated with small data samples such as these, this appears to be consistent with the result of 96 calculated above using the overall data sample.

3.2.3.2 ACN Data

Installation of ACN in-vehicle systems began in the summer of 1997 and reached a high of slightly under 700 in the spring of 1999. The number of deployed ACN systems then declined through the end of the FOT due to de-installations for various reasons. Under the assumption of continuity in service for all vehicles, the total exposure for the FOT was over 500,000 ACN days in the field. This figure is above the original one-year test goal of 365,000 cumulative days in the field (1000 participants for 1 year each). Although the number of subjects was lower than originally planned, the longer test period increased individual exposure time, resulting in a greater cumulative total exposure.

The ACN systems were designed to provide notification in crashes that were likely to involve injuries to the people in the vehicle. This was done in order to avoid burdening the emergency services dispatchers with the reporting of minor "fender-bender" types of crashes. A total of 70 ACN crashes were reported either by the ACN system or the test participants during the FOT. Forty-eight of these crashes were below the ACN-reporting threshold and were reported by the test participants, while twenty-two were above the ACN-reporting threshold. The test data supported the crash algorithm threshold design. Only one of the forty-eight crashes below the ACN-reporting threshold resulted in an injury (an AIS-1), while the other 12 ACN crashes resulting in an injury (up to AIS-3) were above the ACN-reporting threshold (although the ACN did not perform successfully in three of these 12 crashes as discussed later in this section). Basically, the ACN crash detection algorithm performed as intended, responding to all but one of the injury crashes, while reducing the notification of property damage-only crashes by more than 85 %.

Reference 15 estimated that the total number of crashes for 1000 vehicles each driven for a year would be in the range of 28 to 83 (depending on the average number of miles driven per year), with around one-third, or 9 to 27 involving injuries. For the time exposure of this FOT, these numbers translate to 38 to 114 crashes, with 13 to 38 involving injuries. The number of reported crashes for the FOT, both below and above the ACN-reporting threshold, was at the upper end of the expected number of crashes, while the number of injury crashes was at the lower end of the expected number of injury crashes. It is believed that the phenomenon of unreported participation dropouts described above for the CET data collection effort did not affect the ACN data collection effort. The ACN in-vehicle equipment automatically sent biweekly reports to Veridian. In the absence of two consecutive reports, an investigation of the unit was undertaken. In addition, Cellular One reported to Veridian any request for removal of ACN equipment. Therefore, removal from the vehicle or participant departure from the test area should not have produced a significant effect on this sample, as it did for CET participation.

There were 22 ACN crashes above the ACN-reporting threshold. One of these occurred outside of the FOT area in Chicago, Illinois and was not considered in analyzing system performance, as the 1-800 number to the Erie County Sheriff's Office was not then authorized for use from that area. The ACN system functioned as planned in 16 of the remaining 21 crashes, while it did not perform as intended in 5 crashes. Crash event times were obtained for only 15 of the 16 crashes for which the ACN system functioned as planned, crash event times were not available for a crash which occurred outside of the FOT area in Rochester, New York although the Erie County Sheriff's Office was successfully notified of the crash.

3.3 CRASH EVENT TIME MEASURES OF EFFECTIVENESS

A fundamental objective of the ACN FOT was to measure the distributions of the six crash event times listed in Table 3-1:

a. PSAP Notification Time

b. EMS Notification Time

c. EMS Response Time

d. Dispatch Time

e. EMS Travel Time

f. EMS Delivery Time.

These times are directly measurable quantities, and the system benefits objectives (1.1-1.6) were to measure the change in these times that result from deployment of the ACN system. In order to determine the change in these times, it is necessary to be able to compare the measured times against a baseline gauge. For the FOT, the baseline is that derived from CET results. However, the times for each ACN event may also be directly compared to other notification times for that particular event, assuming a non-ACN notification was made. In other words, since crash notification may also be called in to the PSAP manually, these responses may sometimes be compared to the automated call times. Data will be presented for each of the six crash event times noted in the table.

3.3.1 PSAP NOTIFICATION TIME

While ACN calls went directly to the Erie County Sheriff's Office CDF, manual notification calls could go to a number of different PSAPs. Therefore, for purposes of comparison, the notification time will be considered to be the time when the relevant agency received the call. For the ACN calls, that agency is the CDF, while for the CET calls it is the PSAP that first received the 9-1-1 call. A graphical summary of the notification times for successfully completed ACN calls (rounded to the nearest minute) is shown in Figure 3-2. ACN crashes for which there was a notification failure are not included in the data sample. Note that notification time is taken to mean the time between the occurrence of the crash and the receipt and display of the call at the CDF.

There are no notification times greater than 2 minutes in the data sample, and the average time is less than a minute. The data sample for this FOT is considered to be too small to enable significant conclusions to be drawn; however the data are consistent with what was expected. While the number of collisions was small, it was anticipated that the system would consistently complete the emergency call in a short period. The only circumstance that would prolong the notification time was expected to be a possible delay in establishing the cellular phone connection, and this condition apparently did not occur in the data sample.

Veridian Engineering reported that the CDF computer was not synchronized to a standard time source until the FOT had already been underway for some months. If only the collisions which occurred after this synchronization process are considered, one finds that all of the subsequent notification times are either 1 or 0 minute (rounded), and the average time drops to 0.5 minute.

The CET notification times in the data sample are shown in Figure 3-3. The average notification time for CET crashes was 5.6 minutes. It had been theorized that this baseline notification time distribution would have a large peak at small values accompanied by a tail with much larger times. The size and extent of the tail are the features of the distribution that are of the most interest in predicting the impact of an ACN system on medical outcomes of vehicle crashes. Even though the number of data points for this distribution was statistically small, there are a few times which are significantly larger than the other times, indicating the presence of the theoretically expected tail mentioned above. Due to the limited data sample, this operational test has not resulted in any definitive conclusions as to the exact nature of the baseline distribution. It is, however, striking to compare the normalized distributions of ACN and CET crash notification times on the same plot, as is done in Figure 3-4 below. Both distributions have the expected peak at small notification times, while the CET distribution also exhibits the expected tail going out to larger times. While the number of data points is admittedly small, the shapes of the distributions appear to be consistent with those expected, indicating that an ACN system would be successful in reducing the long notification times, possibly by substantial amounts.

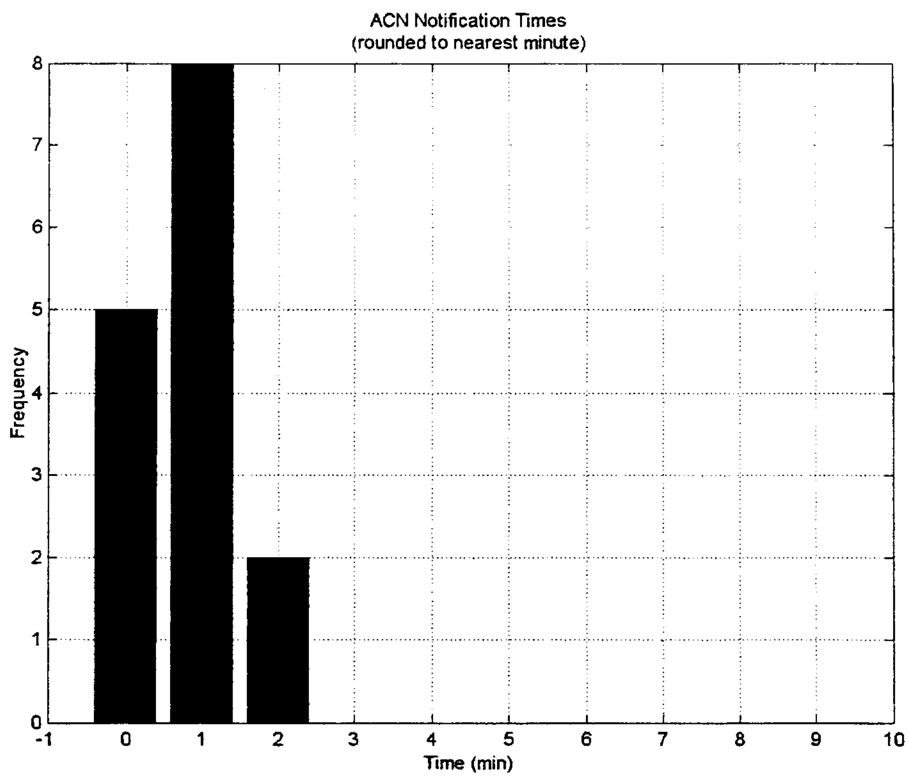

Figure 3-2 ACN Notification Times

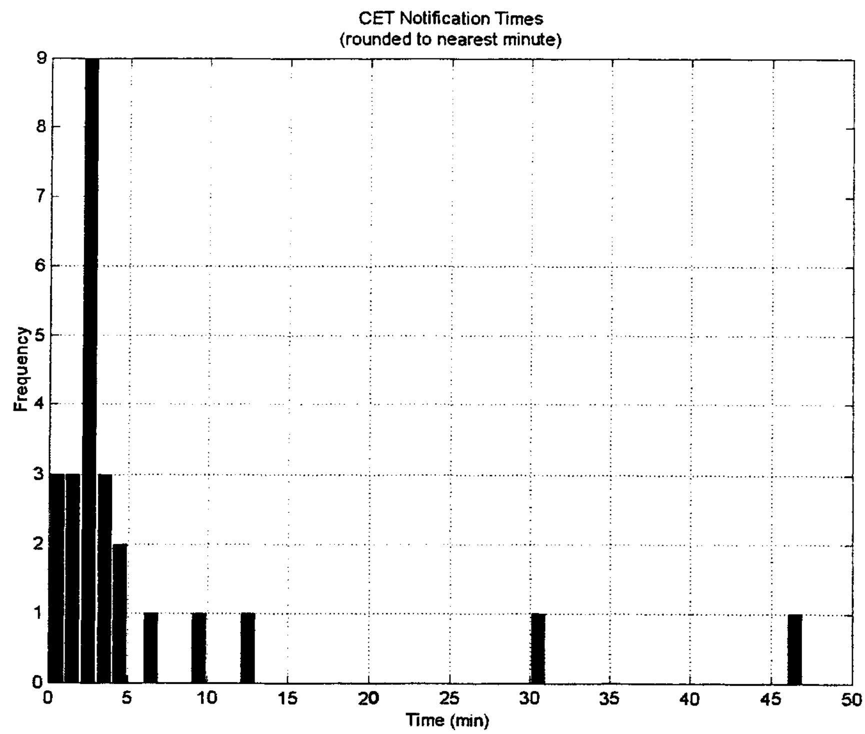

Figure 3-3 CET Notification Times

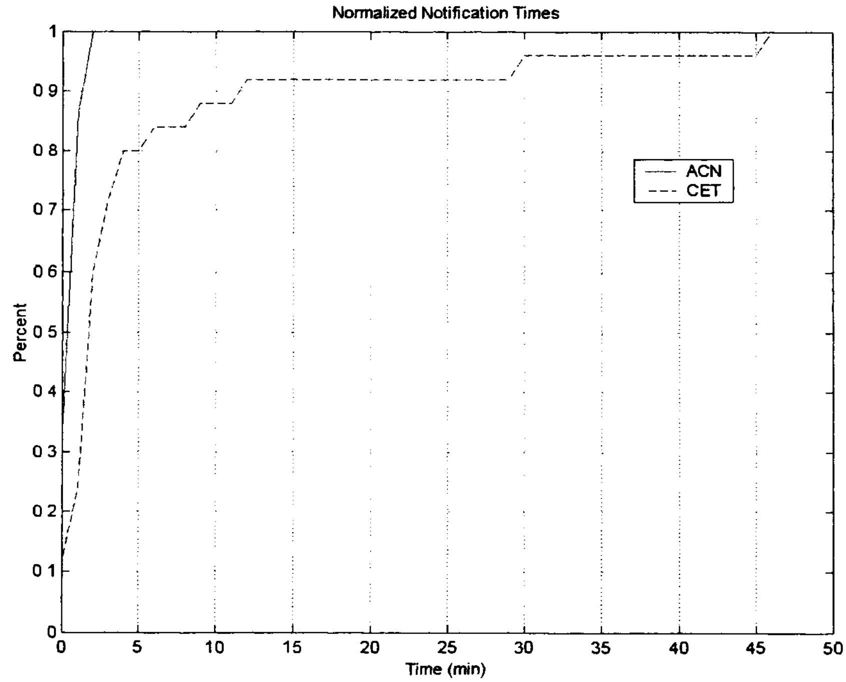

Figure 3-4 Comparison of ACN and CET Notification Time Distributions

For those ACN crashes that were accompanied by manual notification calls, there was no statistically significant difference between the two means of notification. It is worthwhile to note, however, that for 6 of the 15 ACN crashes in the data sample, there were no reported means of notification other than the ACN call. For these crashes, the police arrived on the scene at 4, 4, 5, 11, 13, and 17 minutes, respectively. One might reasonably assume, therefore, that these times could represent a lower bound on the manual notification times for these crashes, as compared with the 0- to 2-minute ACN notification times for these crashes. Therefore, in a significant minority of the observed ACN crashes, the presence of the ACN system clearly reduced the notification times.

3.3.2 EMS NOTIFICATION TIME

The ACN FOT system architecture caused the crash notification message to appear, for all practical purposes, simultaneously at the CDF and at ECMC's MERS dispatch center, an EMS PSAP. Thus, the ACN EMS notification time distribution is identical to the ACN notification time distribution, depicted in Figure 3-2 This is an artificiality of the FOT, due to the architecture of the ACN FOT system and the emergency response system in Erie County. Other ACN systems would not necessarily function in this way. For comparison purposes, Figure 3-5 shows the EMS notification times for those CET crashes for which there was an EMS notification. The plot is divided into 5-minute bins, with the smallest bin representing 0 to 5 minutes. The ACN EMS notification times would all fall in the smallest bin on this plot. In the important, time-critical area of EMS notification, therefore, the ACN system appears to reduce the required time for notification.

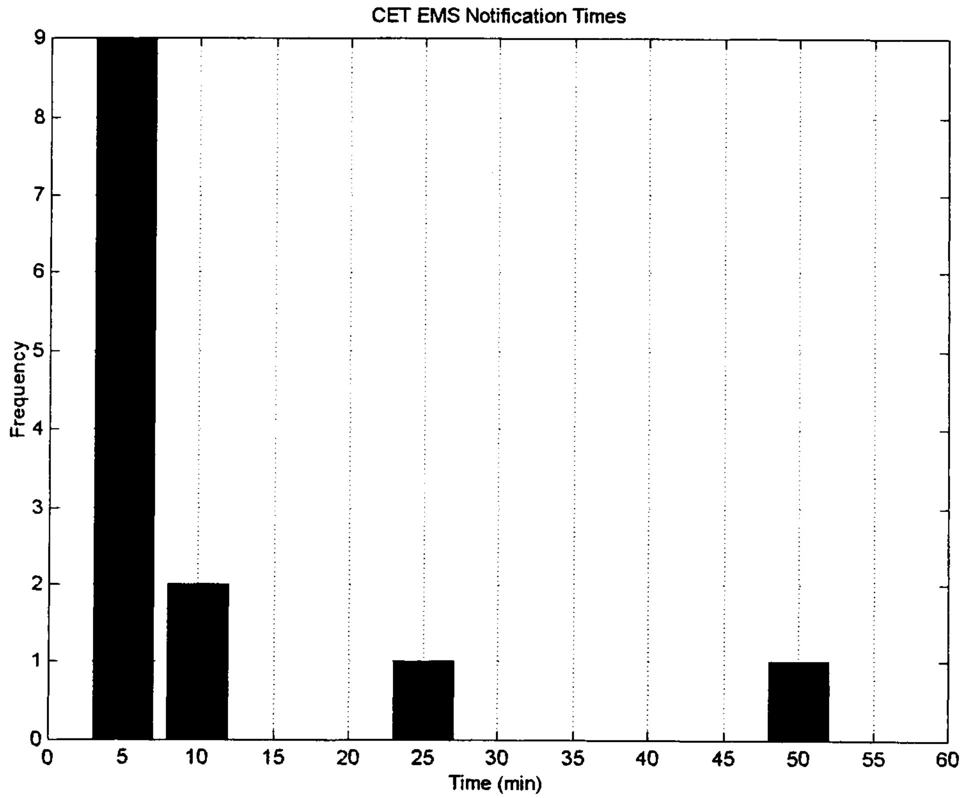

Figure 3-5 CET EMS Notification Times

While the average ACN EMS notification time was determined to be less than 1 minute, the average for CET crashes is over 8 minutes. Again, one should be cautious about drawing any conclusions from such a small data sample, especially with the artificiality introduced by the ACN FOT system architecture, for this measurement

3.3 3 EMS RESPONSE TIME

The EMS Response Time is defined to be the period from occurrence of the crash until the first EMS unit arrives at the crash site. For the ACN collision data, there were only three events that resulted in EMS units being dispatched as a consequence of the ACN notification. The EMS response times for the first EMS units responding to these three crashes were between 3 and 9 minutes. One of the crashes resulted in four EMS units and a helicopter being dispatched, while the other two involved two EMS units each, and the times cited above reflect the values for all of the units that were dispatched. EMS units were actually dispatched in eight of the events, but five of these were as a result of other notification means. This was basically due to two reasons. First, in two of the crashes there were ambulances passing the scene at the time of the crash, and they "responded" to the emergency situation. In three of the other crashes, ACN notification of the appropriate EMS PSAP was delayed while the dispatcher attempted to talk to the driver over the open voice line. During that time, the EMS PSAP was notified by other means. This appears to be an issue related to ACN implementation, and appropriate resolution would require a detailed benefits analysis.

The distribution of CET EMS response times is shown in Figure 3-6 below. As in Figure 3-5, the times have been placed in 5-minute bins (0 to 5, 5 to 10, etc). Note that the three ACN EMS response times would fall in the bins labeled "5" and "10." Due to the scarcity of data, there is very little which may be read into these results

3 3.4 DISPATCH TIME

Dispatch time is defined as the period from EMS notification of the crash until the EMS unit is dispatched to the crash. As described in the previous section, there were only three ACN crashes that resulted in EMS response due to ACN notification, involving multiple responding units. For all the units from those three crashes, the dispatch times ranged from 2 to 9 minutes, with most values clustered near the lower end of the range. For the CET crashes, the dispatch times ranged from 2 to 50 minutes, with most values clustered near the lower values, but including several greater than 10 minutes. One cannot draw any conclusions from these data about the effect of an ACN system on EMS dispatch times.

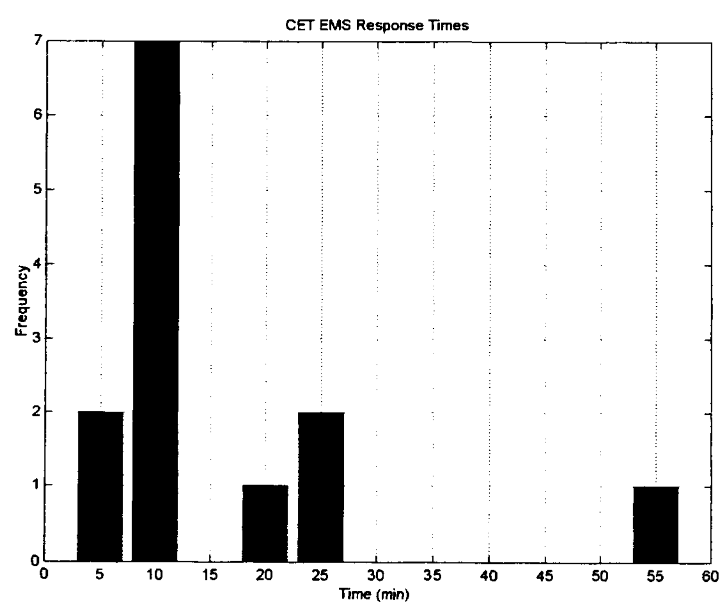

Figure 3-6 CET EMS Response Times

3.3.5 EMS TRAVEL TIME

EMS travel time is defined to be the time elapsed between EMS dispatch and arrival on the crash scene. It was not expected that there would be much effect on this distribution due to the presence or absence of ACN, although the improved location information from the ACN might possibly affect the EMS travel time in cases where a caller without ACN might be confused or unclear about the location. For the three ACN crashes, each of which resulted in multiple EMS responses, the EMS travel times were 0 to 7 minutes. For the CET crashes, the EMS travel times were 1 to 8 minutes. These time distributions are comparable with each other within the statistical limits of the data; therefore, one cannot conclude that there is any difference in EMS travel time between the two data samples

3 3.6 EMS DELIVERY TIME

EMS delivery time is defined to be the period from occurrence of the crash until the EMS unit arrives at the Emergency Care Facility. In the FOT data sample, there was only one ACN crash for which there were data on arrival times at the hospital. For this crash, the three EMS delivery times were in the range of 30 to 48 minutes. For the CET crashes, there were seven crashes that had data on arrival times at the hospital. The EMS delivery times for the units involved in these crashes ranged from 25 to 85 minutes. There is insufficient evidence to determine that there is any effect on EMS delivery times due to the presence or absence of an ACN system.

3.4 NOTIFICATION MEASURES OF PERFORMANCE

Four notification objectives for the evaluation of system performance were given in Reference 2. These were measurements of the notification failure rate for the ACN system, its false notification rate, the Central Dispatch Notification Time, and the Central Dispatch success rate. Each of these will be discussed below.

3.4.1 NOTIFICATION FAILURE RATE

The MOP for the notification failure rate is the number of notification failures experienced in actual or controlled crashes divided by the number of actual or controlled crashes. That is,

Notification Failure Rate = Number of Notification Failures/Number of Crashes

A notification failure is a failure to deliver a crash notification message to the CDF (or the test center for controlled crashes), for any reason. There were a total of 16 ACN crashes for which the system functioned as expected (including the out of area crash in Rochester, NY) and 5 crashes for which the system did not operate properly and notification of the crash was not received at the CDF. This translates to a notification failure rate of 5/21, or 0.24, for the ACN FOT system. Veridian Engineering discussed the failures in Reference 14. One of the five failures occurred when the vehicle battery voltage under heavy load dropped to less than 11 volts and the backup battery was not available due to corroded terminals, this voltage was insufficient for the ACN IVM to place a cellular call. Another was most likely due to damage inflicted on the IVM during the crash. A different system design might potentially have prevented these failures. A third failure was probably due to insufficient cellular phone coverage. The cause of the fourth failure was due to the telephone line to the modem in the ACN dispatch center equipment at the Erie County Sheriff's Office being disconnected for some unknown reason, while the cause of the fifth failure could not be determined. If the anomalous failure due to the disconnected modem line at the Erie County Sheriff's Office is not considered the Notification Failure Rate would be 4/20 or 0.20.

Six controlled crashes utilizing nine vehicles outfitted with ACN systems were conducted at the Veridian crash facility. The notification failure rate for these systems was 1/9, or 0.11. It is believed that the single failure was due to poor cellular phone coverage inside the crash building.

In addition to the actual and controlled crashes there were 128 simulated crashes. These involved the use of an ACN system mounted in a transport case, which did not require a collision to trigger the automated call. The transport case was taken to a roadside location, and the test call was initiated. The original evaluation plan did not call for a calculation of the notification failure rate for these simulated crashes, because it was not believed that they would be subject to the same types of failures as the real crashes (e.g., damage to the IVM, lack of cell phone coverage, etc.). Thus, one might expect a near perfect result, i.e., a failure rate very close to zero. However, the ACN failed to successfully communicate with the CDF equipment in eight of the simulated crashes, a 0.06 failure rate It is believed that the failures were chiefly due to problems with the CDF equipment. As the simulated crashes were performed mainly for the purpose of maintaining a state of awareness at the CDF, the notification failure rate of the simulated crashes is a less meaningful system performance measure than that associated with the real crashes. However, the higher than expected failure rate may be a reflection of unreliable or poorly maintained CDF equipment.

The notification failures in this FOT are thought to be primarily a result of the system design and architecture, or due to human or institutional factors beyond the control of the FOT team. They are not believed to be inherent to an ACN system, and the results of this subsection, as well as those of the next subsection, should not necessarily be construed to be typical of ACN operation.

3.4.2 FALSE NOTIFICATION RATE

A false notification is defined to be the delivery of a crash notification message from a vehicle to the CDF operator for a non-crash event. During the FOT there were a total of 31 false positive notifications, or false alarms, at the CDF. Veridian Engineering in Reference 14 attributed these false alarms to faulty accelerometer mounting in the IVM (13) and unstable or intermittent power supplied to the IVM (18). Veridian has reported that system upgrades could be developed to prevent these types of false alarms from being generated. The MOP for measuring the false notification rate is the number of false notifications experienced, divided by the number of ACN-equipped vehicle years of operation. That is,

False Notification Rate = Number of False Notifications/Years of Operation

Using a value of approximately 1400 years of operation for the period under investigation (see Section 3.2.3.2), the false notification rate for the ACN FOT is 0.022 false notifications/year of operation. One interpretation of this figure is that, with a system such as the one used in this test, on average one might expect to be the originator of a false alarm approximately once every forty or fifty years. From the CDF point of view, however, it is a more serious problem For a metropolitan area with a million ACN-equipped vehicles, a CDF could expect around 22,000 false alarms per year, or around 60 per day, using a false notification rate of 0.022. This figure is almost certainly unacceptable to the CDF. It is likely that improvements in the production process and hardware design could reduce this figure substantially. It is unclear just what would be considered an acceptable level; however, one might assume that an acceptable level is one false alarm per week. Then for the metropolitan case cited above, the false notification rate would have to be reduced to a value of 0 000052, a decline by a factor of around 400 from the value for the system used in the FOT.

3.4 3 CENTRAL DISPATCH NOTIFICATION TIME

For the ACN FOT system architecture, this MOP is identical to that reported in Section 3 3.1 for the PSAP Notification Time. However, depending on the ACN system architecture used these MOPs could be different.

3.4 4 CENTRAL DISPATCH SUCCESS RATE

The Central Dispatch (CD) Success Rate is an MOP designed to assess the ability of the CDF personnel to dispatch EMS equipment based on the information provided by the crash notification message. It is defined to be the number of actual crashes for which sufficiently accurate information was provided by the crash notification message to dispatch EMS equipment divided by the number of actual crashes for which a crash notification message was received That is,

CD Success Rate = "Good" Notification Messages/Number of Messages Received.

For the actual ACN crashes that occurred during the FOT, all of the messages that were sent and received were considered to be good messages, which corresponds to a CD success rate of 1.0. For the controlled and simulated crashes, the CD success rate was judged to be close to 1.0; however, the data for these crashes in the area of CD successes were not viewed with high confidence, since insufficient data were collected to enable detailed analysis.

3.5 MESSAGE AND POSITION ACCURACY

The two accuracy objectives for the evaluation of system performance were the accuracy of the delivered crash notification message and the position location component. These are discussed individually in the following two subsections.

3.5.1 CRASH NOTIFICATION MESSAGE ACCURACY

The accuracy of the crash notification message is a measure of how close the delivered message data elements are to the true values. The MOP for determining the accuracy of the crash notification message is the error rate of the message data elements as compared to the values stored in the central processor of the IVM. Although the plan for evaluating the accuracy of crash notification messages was to compare the data elements received at the CDF with those taken from the IVM, these data were not collected, so this MOP could not be calculated. However, it is believed that due to the CRC error checking employed, no errors were present in received valid messages.

3.5.2 POSITION LOCATION ACCURACY

The MOP for position location component accuracy is the difference, in meters, between the reported location and the actual location. The difference may be due to inherent position location equipment measurement inaccuracies, the position location reporting algorithm, vehicle movement after crash message compilation, the measurement of the actual position, or other difficulties. The reported location is obtained from the delivered crash notification message, while, for the ACN crashes, the actual location is determined by a Differential GPS (DGPS) measurement performed at the site of the crash by the crash investigator. Figure 3-7 shows the differences between the ACN-reported positions and the DGPS measured positions for the actual crashes.

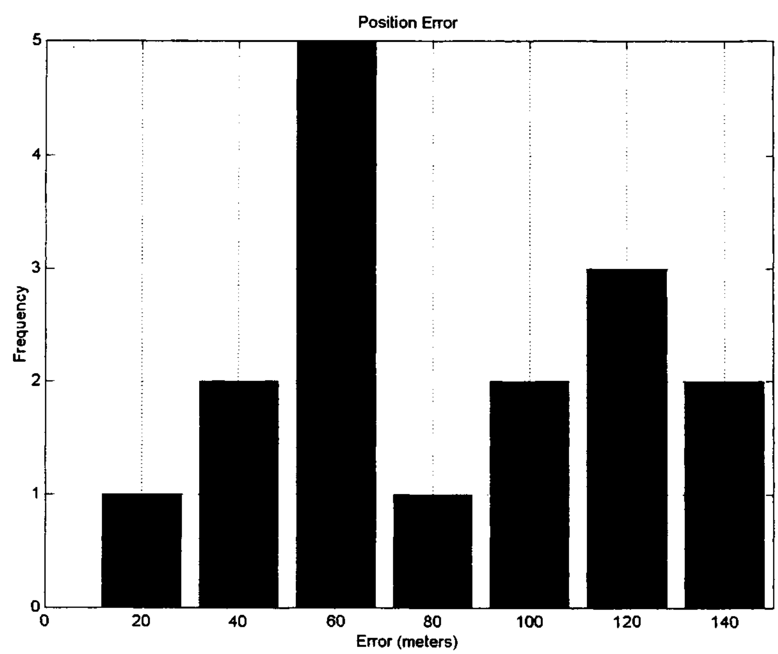

Figure 3-7 Error Distribution for Vehicle Locations Reported by ACN Notification Messages

It is difficult to read anything into this distribution of location errors, due to the small data sample. The error distribution due to GPS errors alone is expected to contain 95 percent of the values at less than 100 meters (the majority of the test period was prior to the removal of induced inaccuracies in the GPS SPS). This is clearly not the case for the distribution in Figure 3-7, indicating that there are other possible sources of error. One likely source of error is that the GPS reading from the vehicle can be up to one second prior to the actual crash, since GPS is sampled only once per second and the last sampled location is sent as the crash location. Another possible source of error may be that the crash investigator may not be able to determine the exact location of the crash. Even if the exact crash location is known, the DGPS measurement point may be different than the actual crash location. This could be due to a number of possible reasons, such as taking the DGPS measurement on the side of the road (for safety). Some combination of these possible error sources is certainly capable of explaining the larger-than-expected measurement errors.

Since 2 May 2000 the intentional degradation of the GPS SPS has been removed and the distribution of GPS errors is expected to be better than 22 m 95 percent of the time. It is expected that, with GPS errors greatly reduced, this system would provide more than adequate accuracy for ACN.

3.6 RELIABILITY MEASURES

Originally, there were six reliability objectives for the evaluation of system performance They consisted of measuring the reliabilities of the in-vehicle system, and its crash sensor, position location, communications, and central processor components, and of the central dispatch equipment. However, the data collected during the FOT do not support reliability calculations for the in-vehicle system or its components. Many of the reliability problems in the database were not resolved, due to the lack of sufficient attention to failure analysis of these problems. Therefore, a reliability measure can be determined only for the CDF equipment (CDFE).

The actual ACN crash data do not contain any failures due to CDFE malfunctions, resulting in a CDFE reliability of 1.0 for the actual crashes. However, the simulated crashes experienced a number of communications failures, and these were usually traced to some problem at the CDF. There were 128 simulated crashes. Of these, there were seven data link failures and one case where the computer at the CDF froze. This leads to a reliability value for the CDFE of 0 94.

3.7 SURVIVABILITY MEASURES OF PERFORMANCE

Survivability is a measure of the ability of the system to function properly during a crash. The four survivability objectives for the evaluation of system performance are to measure the survivability of the in-vehicle system, and its position location, communications, and central processor components.

3.7.1 IN-VEHICLE SYSTEM SURVIVABILITY

For the in-vehicle system, survivability requires that each of the individual system components be capable of performing its function. The MOP for survivability is the number of times the in-vehicle system succeeds in completing its function divided by the number of actual or controlled crashes. That is,

Survivability = Number of Successful Operations/Number of Crashes

For the purpose of survivability calculations, a success is defined to be a crash where the operation of the system is not prevented by collision damage, although there may be other circumstances that prevent the system from functioning properly.

During the FOT, there were 5 (out of 21) crashes for which the ACN system did not function properly. Of these five, one was definitely the result of damage caused by the collision to the communications component. A second may also have been a possible consequence of collision damage, although there was insufficient information to enable a cause to be determined. The other three failures were not due to collision damage. Thus, for the FOT the in-vehicle system survivability is in the range of 0.90 to 0.95. For the controlled crashes, the equipment was undamaged, resulting in an in-vehicle survivability of 1.0. Note again that the results of this FOT are derived from a small data sample.

3.7.2 POSITION LOCATION COMPONENT SURVIVABILITY

For the position location component, survivability is determined as the number of crashes for which the position location component was not damaged by the collision to the extent that it was incapable of performing properly divided by the number of crashes As noted above, although two ACN system failures were possibly related to collision damage, neither was determined to be caused by a failure of the position location component. Therefore, for the small number of crashes that occurred during the FOT, the position location component survivability is calculated to be 1.0.

3.7.3 COMMUNICATIONS COMPONENT SURVIVABILITY

For the communications component, the survivability is determined as the number of crashes for which the communications component was not damaged by the collision to the extent that it was incapable of performing properly divided by the number of crashes. As noted above, one of the FOT crashes caused damage to the communications component. Therefore, the communications component survivability is calculated to be 0.95 for actual above-threshold ACN crashes, which occurred during the FOT.

3.7.4 CENTRAL PROCESSOR SURVIVABILITY

For the central processor component, the survivability is determined as the number of crashes for which the central processor component was not damaged by the collision to the extent that it was incapable of performing properly divided by the number of crashes. There were no crashes for which it was determined that the central processor was damaged sufficiently to cause a failure, so the central processor survivability for this data sample is 1.0.

3.8 AVAILABILITY MEASURES OF PERFORMANCE

Availability is a measure of the ability of a component of the system to function once it is put to use. It assumes that the component survives the actual crash, if not the failure is one of survivability, as previously described, and availability is not an issue. The three availability objectives for the evaluation of system performance were to measure the communications availability, the position location component availability, and to evaluate the ability of the EMS dispatcher to talk directly to the individuals involved in a crash. Each of these objectives will be discussed below

3.8.1 COMMUNICATIONS AVAILABILITY

Communications availability is a measure of how often the communications component is able to complete the cellular call and transmit data. The MOP for communications availability is the number of times the communications component completes the cellular telephone connection divided by the number of attempts. That is,

Communications Availability = Number of Completed Calls/Number of Attempts.

For the actual crashes during the FOT, there were 17 cellular call attempts with 1 failure. This corresponds to a communications availability of 0.94 (the failures due to crash damage to the ACN In-Vehicle system, the disconnected modem at the Erie County Sheriff's Office, low battery power at the vehicle, and unknown causes were not considered in this calculation). Due to the small data sample, this value should be used with caution. The locations of controlled and simulated crashes were not representative of cellular phone coverage and communications availability was not evaluated for these crashes.

3.8.2 POSITION LOCATION AVAILABILITY

Position location availability is a measure of the ability of the position location component to obtain a valid position fix. The MOP for position location availability is the number of times the position location component is able to obtain a position fix in actual, controlled, and simulated crashes divided by the number of attempts. That is,

Location Availability = Number of Valid Position Fixes/Number of Attempts.

For the actual crashes, there were sixteen attempts to establish a position fix, and all were successful, resulting in a position location availability of 1.0. For the controlled crash data, there were 5 successes out of 8 attempts to establish a position fix, a location availability of 0 63. This figure is quite low, and is likely due to the crashes occurring or originating inside a structure that blocked the GPS signals, so this availability figure should not be taken to be representative of GPS availability. For the simulated crashes, there were 118 out of 119 successful position fixes, a location availability of 0 99.

3.8.3 OPEN MICROPHONE AVAILABILITY

The final availability MOP assesses the ability of the dispatchers to talk directly to individuals in a crash. It is the number of times the ACN call is switched to voice mode after delivery of the crash notification message divided by the number of actual crashes for which calls were made and received. That is,

Open Mike Availability = Number of Successful Switches to Voice Mode/
Number of Crash Calls Made and Received.

For the FOT actual crashes, there were 16 calls made and received. Of these, there was 1 in which the CDF did not make successful voice contact with the ACN vehicle, corresponding to an open mike availability of 0.94. For the simulated crashes, 110 out of 119 completed calls resulted in successful voice switches, for an open mike availability of 0.92. Since this is a very desirable feature for an

ACN system, an operational system that would be capable of deployment should have a value much closer to 1.0. Improvements to the FOT system design would probably be able to raise the test value of 0.92 to a more acceptable level.

Section 4

EVALUATION OF USER ACCEPTANCE AND SYSTEM COSTS

4.1 INTRODUCTION

This section presents the results of the evaluations of user acceptance and system cost The objective of the evaluation of user acceptance was to determine participants' impressions of the effectiveness of the ACN system and desired or required features of an ACN system The objective of the evaluation of system cost was to document the costs associated with building and operating the system used in the ACN FOT.

4 2 EVALUATION OF USER ACCEPTANCE

Reference 2 outlined six objectives for the evaluation of user acceptance of the ACN FOT system:

a. Determine the CDF dispatchers' impressions of the effectiveness of the ACN system

b. Determine the PSAP dispatchers' impressions of the effectiveness of the ACN system

c. Determine the driving participants' impressions of the effectiveness of the ACN system

d. Determine the features desired/required by the CDF dispatchers

e. Determine the features desired/required by the PSAP dispatchers

f. Determine the features desired/required by the driving participants.

Data were gathered in the form of surveys that were administered to the driving participants and CDF dispatchers, both at the start of the FOT and towards the end of the test period (after September 1999). The independent evaluator was responsible for formulating the surveys, and Veridian was responsible for administering them. In addition to the surveys, interviews were to be conducted with CDF and MERS personnel, the PSAP personnel, the EMS service provider personnel, and the driving participants involved in each crash of an ACN-equipped vehicle. However, no data were gathered on the impressions and opinions of the PSAP dispatchers (other than at the CDF). Therefore, this report will not discuss the PSAP dispatcher acceptance of the system under test.

Section 4.2.1 describes the driving participants' impressions of the ACN system and their thoughts about its features. A brief summary of the main characteristics of the driver sample selected for the test is given, and their responses to the initial surveys are presented. A smaller number of final surveys were available for analysis and inclusion in this report. An analysis of these surveys is included in Section 4.2.1.

Section 4 2.2 describes the impressions and thoughts of the CDF dispatchers about their contact with the ACN system used in this FOT. The final surveys were available for this user group, so complete results of CDF dispatcher acceptance of this system are presented. Any conclusions that may be drawn from these data are limited in their application, due to the small size of the data sample and other limitations associated with this FOT. These caveats will be noted in the discussion below.

4.2.1 DRIVING PARTICIPANT ACCEPTANCE

The pre-test surveys, administered to the driving participants, contained three main sections. One asked for minimal personal information, the second asked about the importance of ACN system characteristics, and the last covered the relative desirability of an ACN system as compared with other new car options. The survey form is shown in Figure 4-1.

For this report, 651 pre-test surveys were returned and analyzed. An examination of the responses to the personal information section provides a description of this group of test drivers. There were 246 female drivers who responded and 381 males (24 of the surveys left the gender blank). The age distribution of the group is shown in Figure 4-2. The test driver sample was not representative of the population as a whole, being overweighed toward the middle-to-upper end of the age spectrum and underrepresented in the younger age groups. This was likely due to the requirement of a satisfactory credit rating for the drivers imposed by the cellular phone company, as well as the nature of the test. The FOT was directed toward evaluating a system designed to increase the safety of vehicle operation, and it may be that younger drivers were not as interested in this facet of the FOT as older drivers might be expected to be. Figure 4-3 shows the distribution of the number of miles driven annually by the test group. The values range from 1800 to 75000 miles driven annually, with a mean of around 17500 and a median value of 15000.

The second section of the survey asked the participants to rate the features of an ACN system as to their importance. The ratings ranged from 1 (low importance) to 5 (high importance). Figure 4-4 displays the average results of these ratings. It is difficult to read anything into these results, given their fairly uniform levels. There did not appear to be much difference between the ratings of men and women, nor was there any discernible variability with age of the respondents. There was also little variability as a function of miles driven or the amount the participant was willing to pay for an ACN system.

ACN DRIVER SURVEY

As part of the Automated Collision Notification (ACN) operational test, we are asking **volunteer drivers** for feedback concerning your involvement with the ACN device You will also be contacted at the end of the test for a follow-up survey A random number of drivers will also be contacted to set up a personal interview

THANK YOU FOR YOUR COOPERATION IN HELPING US IN THIS IMPORTANT SURVEY

PART A. PERSONAL INFO Cellular Phone # ________________ Current Date ____________

Gender __F or __M Age· ____ # Years driving ____ # Miles driven daily ____ annually _________

PART B. CHARACTERISTICS--*Please circle the number which best describes how important each of the following ACN system characteristics is to you*

I think the ACN system should . . .	**Importance** Low				**High**
1. Activate the alarm only in an actual crash	1	2	3	4	5
2 Automatically determine a crash has occurred	1	2	3	4	5
3. Be reliable (i e. no break downs)	1	2	3	4	5
4. Enable me to talk to emergency personnel during a crisis	1	2	3	4	5
5 Fit well in the car (i e. unobtrusive)	1	2	3	4	5
6 Not limit the area of car operation (i e works anywhere)	1	2	3	4	5
7 Provide a visual display to let me know ACN is working	1	2	3	4	5
8 Require no effort to maintain	1	2	3	4	5
9 Other·	1	2	3	4	5

PART C. DESIRED OPTIONS--*Please rank order the following items one through seven relative to your future willingness to add these options to a* new *car One is first choice, seven is last choice*

OPTIONS	**RANK**
a Anti-theft alarm system	a ___
b Auto power upgrade (locks, windows, mirrors)	b ___
c Automated Collision Notification with cellular phone	c. ___
d. Cellular Phone alone	d. ___
e Keyless entry	e. ___
f Stereo system upgrade	f ___
g Towing and repair service	g ___

What would you be willing to pay for an ACN system, if it is offered as an option on your car? (Check one)

❑ $0-250 ❑ $250-500 ❑ $500-750 ❑ $750-1000 ❑ >$1000

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Figure 4-1 Initial Driving Participant Survey

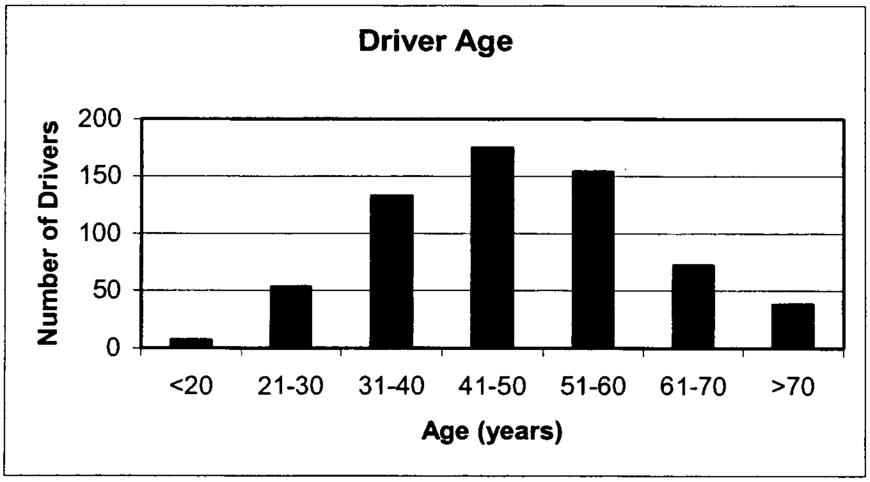

Figure 4-2 Test Driver Age Distribution

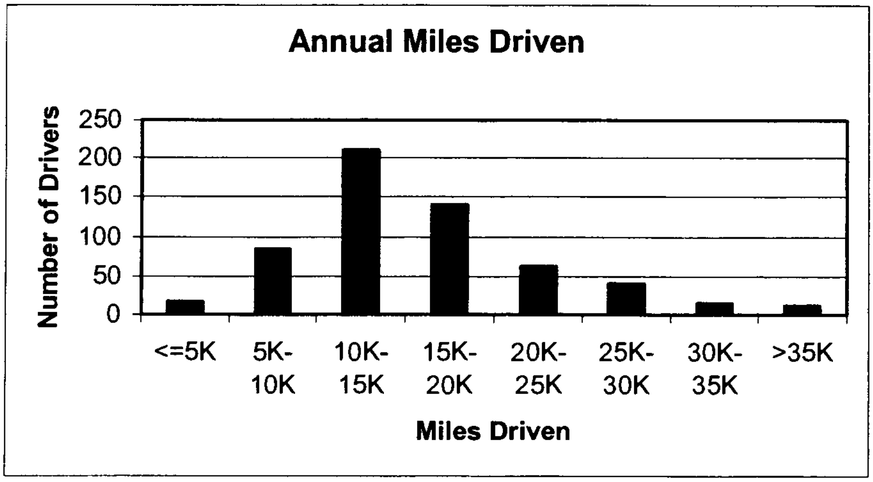

Figure 4-3 Distribution of Miles Driven Annually by Test Population

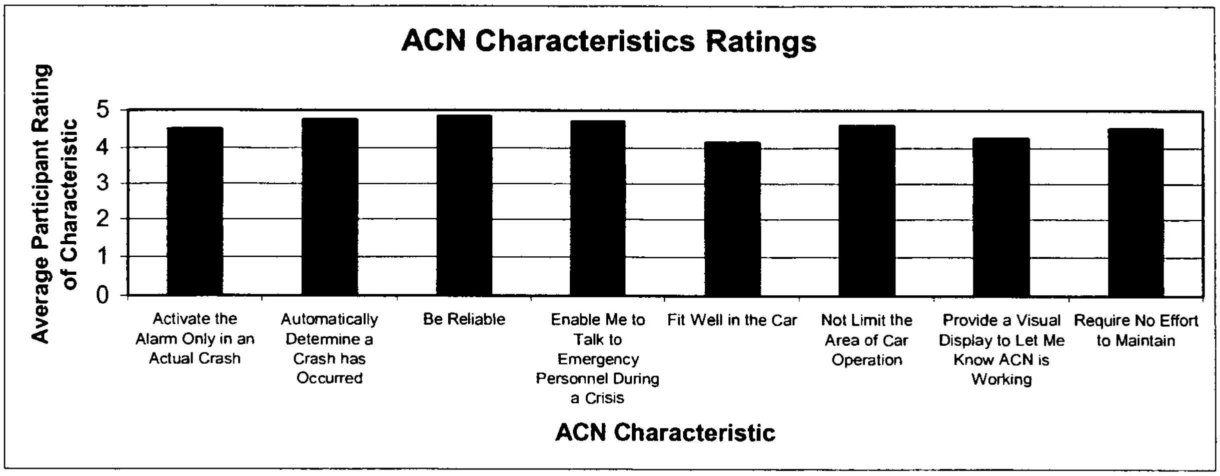

Figure 4-4 Participant Ratings of ACN Characteristics

The third section of the survey asked the participants to rank order their willingness to add various options to a new car. One of the options presented was an ACN system with a cellular phone. Figure 4-5 shows the results of these rankings for the entire participant population. The participants were asked to rank order the list of seven options from most desirable (ranking of 1) to least desirable (ranking of 7); thus, the most desirable feature in the rankings (ACN with cell phone) has the lowest value. This ranking of the ACN system held across both genders and among younger as well as older drivers. Therefore, it may be concluded that the test driver population is very interested in safety. While there were differences in the rankings given some of the other options (e.g., younger drivers were much more interested in the stereo upgrade than the older drivers), all groups rated the ACN with cell phone option at the top and gave it around the same average ranking value.

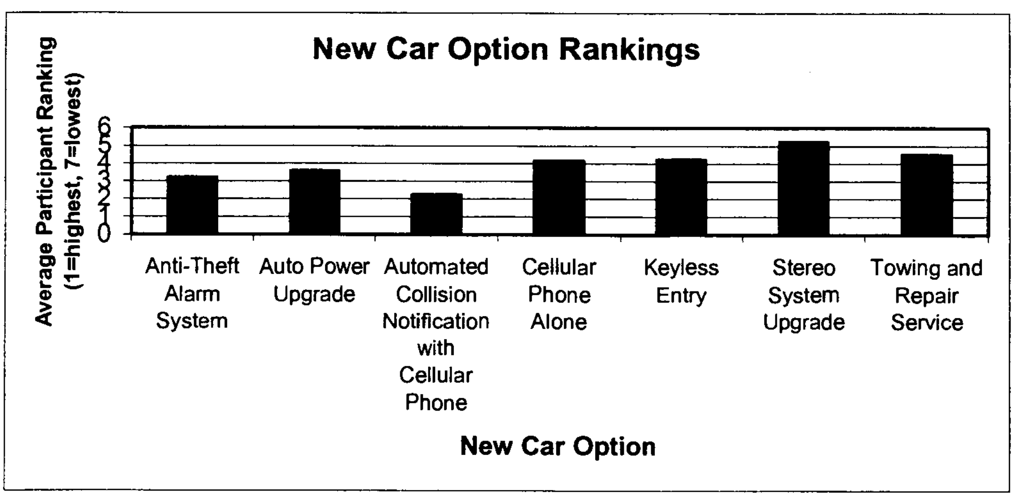

Figure 4-5 Participant Ranking of New Car Options

The follow-up surveys administered to the FOT participants were basically the same as the pre-test surveys, except that they contained two additional questions which dealt with whether the participant experienced a vehicle crash during the test. A total of 381 follow-up surveys were received and analyzed from the FOT participants. As expected, the personal information characteristics from the follow-up surveys were very similar to those from the pre-test surveys. Specifically, the average age, average miles driven annually, and ratio of males to females were comparable among the two surveys. In addition, there was not a significant change in the ratings of the ACN system features or in the ranking order of the new car features. It should be noted that, as in the pre-test surveys, the ACN system with cellular phone was the highest rated new car option on the follow-up surveys.

An analysis was done on the subset of participants who had a vehicle crash while using the ACN system. Out of the 381 people who returned follow-up surveys, 55 noted that they had been in a crash (these included crashes that were below the threshold set for ACN automatic notification). Among this group, there was a higher average rating on the follow-up surveys compared to the pre-test surveys for the categories "Be Reliable" and "Enable Me to Talk to Emergency Personnel During a Crisis." This suggests that the people who experienced crashes have become more concerned that the ACN is operational than they were previously. In addition, the crash victims giving added importance to the involvement of emergency personnel may show that having a vehicle crash has enhanced their awareness of the risk of injury while driving.

4.2.2 CDF DISPATCHER ACCEPTANCE

Surveys were administered to the CDF dispatchers at the beginning of the FOT and after September 1999. Figure 4-6 is a copy of the initial CDF dispatcher survey. There were 16 initial surveys administered, 14 of which were completed, while 13 follow-up surveys were completed and returned. The two surveys were identical, except that the follow-up survey contained questions about whether the dispatcher had been involved in using the ACN equipment. There were no personal questions on the surveys, with the exception of spaces to indicate the number of years the dispatcher had been on the job and job title There were a wide variety of years of experience represented in the survey results, ranging from newly hired to 24 years on the job.

4.2.2.1 Initial Dispatcher Impressions

The surveys were composed of two main sections, one that asked the dispatchers to rate the importance of some of the ACN system characteristics, and a second that asked for their opinions on the desirability of some suggested additional features. In analyzing the dispatcher surveys, the sample was divided into two groups by years of service: those who had fewer than ten years of service, and those who had been on the job for over ten years. These two groups will be referred to as the shorter-period of service and longer-period of service employees, respectively. The initial survey responses from these two groups are presented and compared below.

ACN CENTRAL DISPATCHERS SURVEY

As part of the Automated Collision Notification (ACN) operational test, we are asking **central dispatchers** for feedback concerning your involvement with the ACN device. You will also be contacted at the completion of the test for a follow-up survey. A random number of dispatchers will also be contacted to set up a personal interview.

THANK YOU FOR YOUR COOPERATION IN HELPING US IN THIS IMPORTANT SURVEY

PART A. PERSONAL INFO Location ______________ Current Date ________

Years on the job ________ Position or Title ________

PART B. CHARACTERISTICS--*Please circle the number which best describes how important each of the following ACN characteristics is to you.*

I think the ACN system should . . .	Importance Low..................High				
1. Allow me to talk to the victim	1	2	3	4	5
2. Display reliable, accurate info location on position map	1	2	3	4	5
3. Enable me to know if it's a car accident versus any other kind of emergency	1	2	3	4	5
4. Have a low false alarm rate (i.e. don't report an accident if it didn't occur)	1	2	3	4	5
5. Let me transfer data via FAX	1	2	3	4	5
6. Make available accident severity information	1	2	3	4	5
7. Present data in a easily usable manner	1	2	3	4	5
8. Provide crash info in a straight forward, understandable way	1	2	3	4	5
9. Provide a visual and audible call alert (i.e. I can see and hear the alarm)	1	2	3	4	5
10. Other	1	2	3	4	5

PART C. DESIRED FEATURES--*Please circle the number which best describes how desirable each of the following ACN features is to you.*

I would like the ACN system to . . .	Desirability Low..................High				
a. Alert me when an air bag deploys	1	2	3	4	5
b. Estimate crash severity	1	2	3	4	5
c. Indicate if seat belts are in use	1	2	3	4	5
d. Provide me with number of occupants in vehicle	1	2	3	4	5
e. Provide me with position of occupants in vehicle	1	2	3	4	5
f. Other	1	2	3	4	5

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Figure 4-6 Initial Dispatcher Survey

The results of the survey section on system characteristics are summarized in Figure 4-7. While many of the characteristic ratings by the two groups are similar, there are a few areas where there appear to be some differences. The shorter-period of service employees were more interested in being able to talk to the crash victims and to receive information on the severity of the crash than the longer-period of service employees, who were more concerned with having a low false alarm rate and a multiple-style alerting mechanism. In general, both groups were least interested in the FAX feature of the ACN system, which enabled them to fax crash data to the appropriate PSAP for the ACN call.

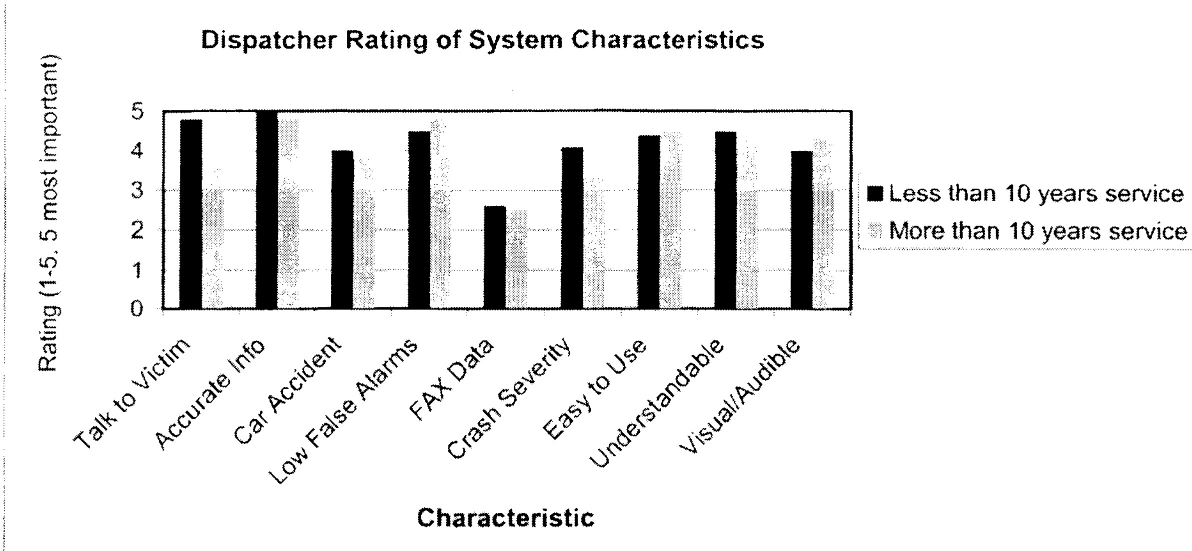

Figure 4-7 Pre-Test Dispatcher Rating of System Characteristics

The dispatchers' pre-test opinions on the desirability of adding some suggested features are shown in Figure 4-8. From this figure, it is evident that the shorter-period of service employees find the suggested potential features to be more interesting than the longer-period of service employees do. This could simply be a manifestation of the greater flexibility one might expect from newer employees than from employees who have been doing the same work in the same way for a longer time. It should be noted that the suggested features were selected to appeal to an audience with more medical background, since they all deal with information that emergency medical personnel might want to know, in order to prepare for the appropriate treatment. Therefore, they would not necessarily be of interest to police dispatchers.

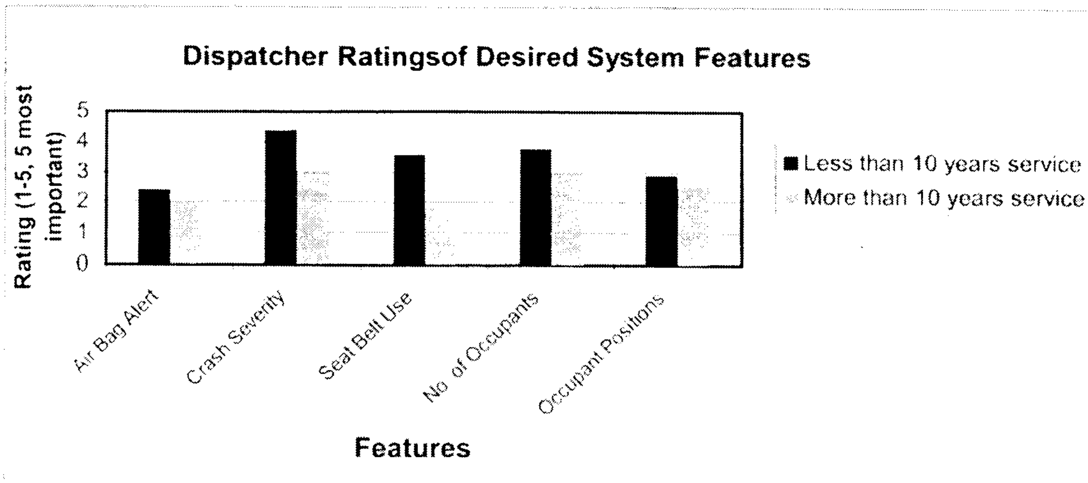

Figure 4-8 Pre-Test Dispatcher Ratings of Suggested Desired System Features

There was also space allotted on the surveys for individual comments. In general, the CDF dispatchers were not supportive of the introduction of the ACN equipment into their workspace. Of the 14 initial surveys, six had written comments suggesting that the equipment be moved to some other part of the room, in order to pass the responsibility for handling ACN calls to the complaint writers, instead of the dispatchers. This indicates a certain lack of support for the program among those who were expected to participate and help evaluate the effectiveness and usefulness of the equipment. The comments included such phrases as:

a. "The dispatchers are too busy to be distracted"

b. "Dispatchers are frequently busy with radio responsibilities and should not be interrupted or distracted during peak times"

c. "[ACN equipment] should not be on this side of the room, as there are too many responsibilities on this side"

Clearly, the ACN equipment was not seen as something that could help the dispatchers do their job, or improve the capability to save lives. The dispatchers seemed to feel that they were overburdened with responsibilities, and viewed ACN as a potential additional burden, rather than as a means of making their work easier and more efficient. To them, it was an "interruption" or a "distraction" from their main responsibilities. One dispatcher said, "If the alarm is going off, and I have a [police] car that is in trouble, my attention will first go to the deputy as I feel his or her safety comes first." It seems clear that there was a certain lack of acceptance of the ACN equipment on the part of a number of dispatchers, which resulted in the anticipation that it would simply be an annoyance, or, worse, would distract them from their work.

Some of the dispatchers seemed somewhat more willing to use the equipment. These individuals tended to be those who had been on the job for shorter periods, although even some of these indicated that they would have preferred for the responsibilities for the ACN equipment to be handled by the complaint writers.

4.2.2.2 Follow-up Dispatcher Impressions

A survey similar to the initial one described above was administered to a number of dispatchers in November 1999. The only difference between the two surveys was that the follow-up included several questions on the dispatcher's experiences with the ACN system. As in analyzing the dispatcher initial surveys, the sample was divided into two groups by years of service: those who had fewer than ten years of service, and those who had been on the job for over ten years. The results of the follow-up survey responses from these two groups are presented and compared below.

The results of the survey section on system characteristics are summarized in Figure 4-9. According to the results of the follow-up study, the shorter-period of service employees are still more interested in talking to the victims than the longer-period of service employees are, but the difference in interest in crash severity information between the two groups has shrunk to statistical insignificance. Newer employee interest in the accuracy of the information provided has increased, however, while that for the longer-period of service employees has pulled back, making this a more noticeable difference in the follow-up survey. While the ability to FAX information is still at the bottom of the list for both groups, it has significantly moved up in interest to the shorter-period of service employees. Longer-period of service employees are still more interested than newer ones in a low false alarm rate and a multiple-style alarm.

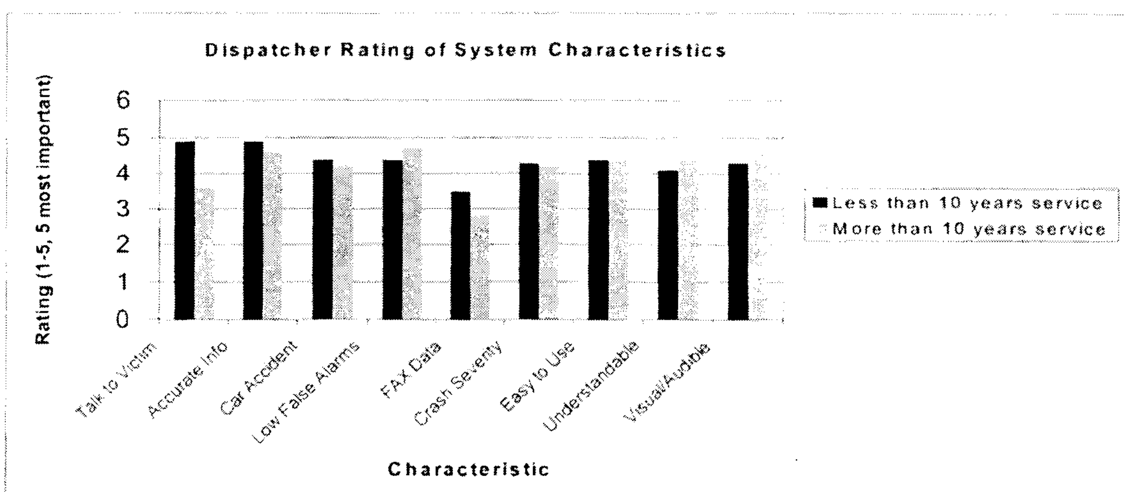

Figure 4-9 Follow-up Dispatcher Rating of System Characteristics

If one compares the follow-up ratings of the shorter-period of service employees with those they made in the initial surveys, and ignores differences smaller than 0.2, five of the ratings of system characteristics increased, three remained around the same, while only one decreased. For the longer-period of service employees, four ratings of system characteristics increased, three were unchanged, while two decreased. One interpretation of these results might be that the dispatchers, especially the newer ones, found the ACN system to be more useful than they expected it to be. Note that we are again dealing with a small data sample, so one must be careful in drawing strong conclusions.

The dispatchers' follow-up opinions on the desirability of adding some suggested features are shown in Figure 4-10. While the shorter-period of service employees are still more interested in being given an airbag deployment alert, crash severity measure, and indications of seat belt usage, now the longer-period of service employees are more interested in knowing the number and positions of the vehicle's occupants. In the pre-test survey, the longer-period of service employees were consistently and significantly less interested in all of the suggested features. The interest of both groups in the suggested features trended upward fairly strongly between the two surveys. This may suggest a stronger interest in the ACN system as a result of increased familiarity with the system.

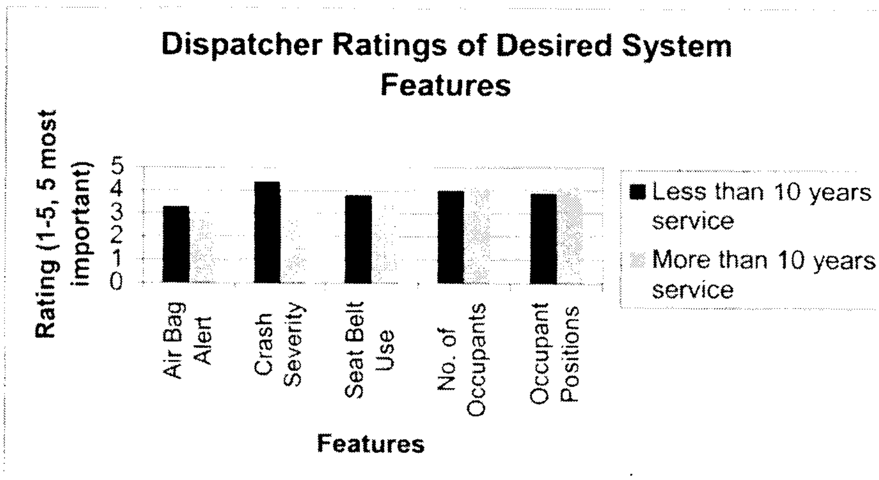

Figure 4-10 Follow-up Dispatcher Ratings of Suggested Desired System Features

4.3 EVALUATION OF SYSTEM COSTS

The goal for the evaluation of system costs was to document the costs associated with building and operating the system used in the ACN FOT. These costs were to include capital, development, installation, and maintenance costs. It was recognized that the architectural choices made in implementing an ACN system on a large scale would have a significant effect on both the costs associated with the deployment of an ACN system and on the distribution of those costs among the public, private and consumer sectors. Therefore, no attempt was made to estimate the costs that would be associated with the large-scale implementation of an ACN system, which would be dependent on the architecture selected.

The objectives of the cost evaluation were the following:

a. Record the capital costs for the components of the in-vehicle system and its components

b. Record the costs of developing the in-vehicle system

c. Record the in-vehicle system installation costs

d. Record the capital costs for the dispatch center equipment

e. Record the costs of developing the dispatch center equipment

f. Record the dispatch center equipment installation costs

g. Record the dispatch center training costs

h. Record the repair and maintenance costs for the in-vehicle system

i. Record the repair and maintenance costs for the dispatch center equipment.

The required capital, development, installation, and maintenance costs, to the extent they were available, were supplied by Veridian Engineering using standard accepted accounting practices. These costs are reported in the following paragraphs.

4.3.1 IN-VEHICLE SYSTEM CAPITAL COSTS

Veridian Engineering reported that for a production run of 1,000 units the In-Vehicle System capital costs were $995 per unit. The In-Vehicle Module, which included the GPS receiver, accelerometers, and data modem, cost $549. The remainder of the In-Vehicle System, which included the cellular phone equipment, GPS antenna, and back-up battery, cost $446. It should be noted that these in-vehicle system capital costs are not considered to be necessarily representative of those for a future implementation of an ACN System as they were for a prototype system and were incurred in the 1996 through 1997 period; costs for this type of equipment may change dramatically over a period of a few years.

4.3.2 IN-VEHICLE SYSTEM DEVELOPMENT COSTS

Veridian Engineering reported that the costs of developing the In-Vehicle System were $1,412,811. These costs included design and development of the IVM hardware, firmware, and software; development of communications and crash severity software; development of manufacturing drawings; system integration efforts; and conducting component and system tests. It should be noted that these in-vehicle system development costs are not considered to be necessarily representative of those for a future implementation of an ACN System as they were for a prototype system.

4.3.3 IN-VEHICLE SYSTEM INSTALLATION COSTS

Veridian Engineering reported that the costs of installing the In-Vehicle Systems were approximately $57,000 or approximately $70 per installation. These costs included charges to the ACN FOT contract by Veridian and Cellular One's project cost sharing.

4.3.4 DISPATCH CENTER CAPITAL COSTS

Veridian Engineering reported that the dispatch center equipment capital costs were approximately $23,300. This covered personal computers, uninterruptible power supplies, fax modems, Ethernet cards, phone equipment, and purchased software for the dispatch equipment at both the Erie County Sheriff's Office and ECMC.

4.3.5 DISPATCH CENTER DEVELOPMENT COSTS

Veridian Engineering reported that the costs of developing the dispatch center equipment were $152,400. These costs included dispatch system design, design and development of dispatch communications software, design and development of dispatcher user interface, system integration efforts, and conducting dispatcher system component tests

4.3.6 DISPATCH CENTER INSTALLATION COSTS

Veridian Engineering reported that the costs of installing the dispatch center equipment at the Erie County Sheriff's Office and ECMC were approximately $5,600. These costs included expenses to install computer equipment and telephone lines.

4.3.7 DISPATCH CENTER TRAINING COSTS

Veridian Engineering reported that the dispatch center training costs were approximately $5,000. These costs included expenses for initial training and continuing tests at the Erie County Sheriff's Office and ECMC.

4 3.8 IN-VEHICLE SYSTEM REPAIR AND MAINTENANCE COSTS

Veridian Engineering reported that the repair and maintenance costs for the in-vehicle system were approximately $129,000. These were broken down roughly as $80,000 for service calls, and $49,000 for software upgrades. The service call costs covered over 300 service calls, the investigation of false crash notifications, and the removal of faulty In-Vehicle Modules. The software upgrade costs included the development of software upgrades to improve system operation while in the cellular roaming mode and to inhibit false crash notifications due to unrealistic spikes in accelerometer readings or unstable power conditions, and installation of the upgraded software. They do not include routine operating costs.

4.3.9 DISPATCH CENTER REPAIR AND MAINTENANCE COSTS

Veridian Engineering reported that the repair and maintenance costs for the dispatch center equipment were approximately $15,000. These costs included expenses for routine maintenance checks, updating software, and resolving voice quality problems. They do not include routine operating costs such as monthly phone costs.

Section 5

EVALUATION OF INSTITUTIONAL ISSUES

5.1 INTRODUCTION

The objective of the evaluation of institutional issues was to document those issues that were encountered during the ACN FOT, along with their resolution and recommendations concerning them. The collection of data on institutional issues was the responsibility of the entire ACN FOT team As institutional issues occurred, they were entered into an institutional issues log by the independent evaluator for tracking. These issues were discussed at meetings of the ACN FOT team and any progress on their resolution entered into the log. Near the end of the test period, the issues were reviewed and recommendations formulated concerning them. Two types of issues were documented – those that could impact the development and deployment of ACN systems and those that either impacted or had the potential to impact the conduct of the FOT. These two types of issues will be discussed separately.

5.2 ACN SYSTEM ISSUES

Five institutional issues were noted during the ACN FOT that could impact the development and deployment of ACN systems. These included both legal issues and technology issues. The ACN system issues were the following:

a. ACN system liability

b. Access to ACN data

c. ACN system architecture

d. Vehicle position reporting

e. Ability of drivers to understand the ACN technology.

5.2.1 ACN SYSTEM LIABILITY

During the planning phase of the FOT concerns were raised over potential liability if the ACN system failed to work or if help was not provided in time to injured participants. The cause for this issue is the litigious society that we live in; the legal foundations for these concerns were not addressed Potential effects of this issue for the FOT included the financial and manpower requirements of defending lawsuits, as well as the resulting negative publicity for the ACN system.

The first and foremost method of resolution for the FOT was to design the ACN system to be safe and reliable. In addition, the system was designed to not change the way emergency responders deal with highway emergencies. The ACN system was implemented as a tool to augment and enhance existing procedures. In this way, the ACN system could not be considered at fault if an emergency response was inadequate.

In addition, Veridian Engineering developed a Disclosure and Warning Statement and Waiver using proper legal terminology to be signed by owners of ACN-equipped vehicles and a witness The disclosure and warning statement noted that the ACN system was an experimental system and there could be instances where this experimental system fails or does not perform to expectations. It also stated that Veridian Engineering cannot and does not guarantee that the ACN system, in the event of a crash, will bring emergency assistance any sooner than it otherwise might come. The waiver released the FOT partners from all liability for crashes or injuries that arise in connection with participation in the ACN FOT

Other approaches to mitigating liability for ACN systems noted during the project include the development of accepted operating standards, dispatcher and notification center certification standards, and accepted procedures and protocols for interfacing and coordinating between private and public emergency response systems. It is believed that if agencies involved in responding to emergencies can show that they are applying accepted standards, frivolous litigation challenges can be reduced, and the litigation process, where liability is justifiably questioned, will be more straightforward.

5.2.2 ACCESS TO ACN DATA

The ACN FOT system collected data that can provide information concerning collisions and the operation of the vehicle (e.g., position, velocity, heading, and acceleration). It was considered possible that vehicle owners, insurance companies, or law enforcement officials would seek access to this data in an attempt to establish fault in a crash. The cause of this issue was a concern that the data collected during the FOT could be subpoenaed during litigation involving ACN-equipped vehicles.

Possible effects of this issue include vehicle owners being reluctant to install an ACN system if ACN data may be used to establish their fault in a crash, and the partners of the ACN FOT being subject to lawsuits for either supplying or not supplying the data upon request. If ACN systems become perceived as a storehouse of data that can be used to prove fault in a crash, it could have a negative affect on public acceptance. This could become a deterrent to widespread use and thereby limit the potential positive impact of ACN systems on public safety. On the other hand, there may be situations when this information could have a beneficial impact (e.g., furthering justice in cases of clear wrongdoing such as a hit and run accident).

The resolution of this issue for the FOT included the development of a Disclosure and Warning Statement and Waiver to be signed by owners of ACN-equipped vehicles. The disclosure and warning statement noted that the ACN system could cause the creation of an official record of a crash that otherwise would not be required to be reported under New York State law. The waiver granted Veridian Engineering the right to use, at its sole discretion, any and all data gathered from the participant and his or her automobile as part of the program, with the exception of revealing the participant's identity or personal information to persons other than the participants in the program (which included the Erie County Sheriff's Office).

In addition, it was determined that Veridian Engineering would use crash investigators that were New York State certified and not subject to subpoena in accordance with a clause of the Veridian Engineering contract. While this contractual clause has been tested and found to be effective, it is always possible that new legislation could be put in place that would weaken these protections. Also, National Automotive Sampling System (NASS) data protection procedures were applied to all data collected for the ACN FOT, and the data most likely to be of interest to a potential subpoena (e.g., speed prior to a crash) was not displayed at the Sheriff's Office computer console. Continuing requests for data were to be referred to NHTSA, the Government agency for which the FOT was conducted.

While this issue never arose during the FOT, it is expected that it will apply to future ACN deployments, although for an operational system it might only apply to the information sent in the crash notification message as there might not be any data collected from the in-vehicle system. It is recommended that as requests for ACN data are to be expected, the architecture of future ACN systems should either support the provision of this information, or the ACN systems should not collect or save data that could be used against drivers. In the former case, the recruitment/sales literature should state the information that is available and the policies and procedures for the provision of this information. It is expected that the information available and the policies and procedures will be dependent on the architecture of the system (e.g., whether the system is run by a private enterprise or Government agency, or whether the notification message is sent to a regional/national central dispatch facility or directly to the PSAPs). This issue will require more consideration and work to resolve not only for ACN applications, but also for other ITS applications as well.

5.2.3 ACN SYSTEM ARCHITECTURE

As discussed in Section 2, there are two possible response network architectures, private and public, for use with ACN systems. This issue concerns whether private companies should provide ACN service to subscribers for a fee or whether ACN service should be available to all callers by dialing the national emergency number 9-1-1. The ACN FOT response network was a hybrid architecture containing features of both the private and public network architectures. While crash notification calls were made via a 1-800 number to a single regional message center for the Erie County area, that center was an operational PSAP. It should be noted that the architecture choice for the ACN FOT was based on what was technologically feasible and financially affordable for the FOT and a desire to avoid changes to the emergency response system during this technology demonstration. It was not meant to be the architecture choice for future deployed ACN systems.

While this issue concerns whether ACN systems should employ a private or public response network, it is likely that the future response network architecture will be a combination of both the private and public architectures. In the absence of an ACN public response network, the first commercial crash notification services have already deployed their versions of private response network architectures. These will continue to exist at least until a nationwide ACN public response network is deployed, which is likely to occur over a period of years. It should be noted that as the eventual ACN system architecture evolves, there will be a need for a standardization of methods, protocols, and messages to allow for interoperability between systems and equipment.

The use of a 1-800 number in the ACN FOT ensured that all ACN calls made from the test vehicles went to a single dispatch location, thus limiting the cost of installing dispatch equipment for this technology demonstration. However, it raised concerns on the effects of the use of a 1-800 number on system operation. These concerns included whether cellular calls would be completed or data calls could be completed when the vehicles were outside the local calling area and the phones were operating in roaming mode and the lack of priority for 1-800 calls if cellular service was congested in the crash location. The ACN FOT system addressed these issues by allowing 9-1-1 calls from the vehicle to preempt ACN calls and not interrupting an in-progress 9-1-1 call. In addition, the ACN system prompted the vehicle occupant to call 9-1-1 if the 1-800 number call to the Sheriff's Department could not be completed. It is expected that as cellular phone usage continues to increase, that issues related to the ability to make calls when roaming will gradually be resolved.

5.2.4 VEHICLE POSITION REPORTING

This technical issue concerned the position(s) to be reported by the ACN system. Possible positions that could be reported by the ACN System include the position of the vehicle at the time of the crash (or the last available position before the crash), the final resting position of the vehicle after the crash, and a time series history of vehicle positions prior to the crash. The ACN FOT system reported the position of the vehicle at the time of the crash and a series of the 10 most recent position measurements, allowing a plot of the vehicle track to be displayed at the dispatcher's console. For an ACN system based on dialing 9-1-1 and routing calls directly to a PSAP or for ACN vehicle systems to be able to work with different private ACN call centers, a standard position reporting scheme will need to be selected and agreed upon. It is expected that industry standards such as the SAE On-Board Land Vehicle Mayday Reporting Interface (J2313) for vehicle to response center messages would play an important part in this effort.

In addition there was a concern about the effect location accuracy would have in determining the jurisdiction a crash occurred in. This would occur when a crash took place near a jurisdictional boundary. The GPS positions reported by the ACN FOT system were normally accurate to within 100 meters; thus it was considered possible that a crash might be reported in one jurisdiction when it occurred in another. The ACN FOT chose to address this issue by placing an error ellipse about the reported position on the geographical display at the central dispatch facility to alert the dispatcher to the potential for the vehicle to be in another jurisdiction. This issue may be resolved through operational procedures at the PSAPs provided they are given information such as an error ellipse to alert them to the potential error in a reported position or are trained in understanding the potential errors associated with reported positions (GPS or wireless network).

5.2.5 ABILITY OF DRIVERS TO UNDERSTAND THE ACN TECHNOLOGY

It was noted during the ACN FOT that some owners of ACN-equipped vehicles had difficulty understanding how the system operated. There were two primary causes for this issue being generated. The first was a difference in the expectations of crash notification between some drivers of ACN-equipped vehicles and the way the system was designed to operate. The ACN system was designed to detect crashes and place a call based on the likelihood of injury to the vehicle's occupants. This was done to avoid generating emergency response calls when there were no injured occupants, since it was felt that if assistance was needed the occupants could still place a non-emergency call. Some drivers had the expectation, however, that all crashes would generate a call The second cause was the observation that some drivers or passengers were unsure of how to operate the system. For example, in one ACN collision during which the driver of the ACN vehicle had exited the vehicle prior to the voice connection being made; an injured elderly female passenger was apparently unable or unwilling to use the cellular phone to talk to the dispatcher. In another crash it was thought that the elderly driver's inexperience with the cellular phone might have contributed to the difficulties experienced with the voice communications link.

The effects of this issue are a potential questioning of whether the ACN system is working by the drivers, a possible distrust of the system and its capabilities, and reduced effectiveness of the system. Possible methods of resolution for this issue in future ACN deployments include the following:

a. adding an indicator to the in-vehicle ACN equipment to indicate that a crash has been sensed but that no emergency call is being placed due to the low likelihood of injury

b. adding a single-button, manual crash-reporting capability to the ACN system

c. improving the operating instructions

d. educating the public about the capabilities of ACN systems and how they operate.

5.3 FOT ISSUES

Nine institutional issues were noted that either impacted or had the potential to impact the conduct of the FOT. These included resource, organizational and management, and evaluation issues. The FOT issues were the following:

a. Required resources were underestimated

b. Projects with multiple partners are difficult to manage

c. Participant commitment

d. Dependence of results on FOT architecture

e. Synchronization of event times

f. Paucity of ACN events

g. Notification of CET crashes

h. Driver denial of a crash event

i. Confidentiality of medical records.

5.3.1 REQUIRED RESOURCES WERE UNDERESTIMATED

The resources required to conduct the FOT were underestimated. These resources included time and level of effort required and the resulting costs, as well as the types of experience required by project personnel. Areas of underestimation included the time and effort required for the following:

a. Recruitment of participants and the installation of ACN and CET equipment

b. Public relations and interacting with the public

c. Equipment maintenance revision efforts.

The original FOT plans considered the recruitment of participants and the installation of ACN and CET equipment to be short-term efforts that could reasonably be accomplished. However, participant recruitment and equipment installation turned out to be ongoing activities that required much more effort than expected. Recruitment activities included the following:

a. Creating articles and ads for submission to news publications

b. Time spent calling and coordinating with publications in getting articles/ads published

c. Television interviews on all local stations, several times during the project

d. Appearances on local radio shows

e. Tours and interviews given to local newspaper reporters

f. Development of information brochures for distribution at shows and shopping centers

g. Setting-up and taking-down displays at shows and malls

h. Efforts calling local businesses to request cooperation in recruiting efforts

i. Attending numerous shows and fairs and community events (e g., Erie County Fair and Buffalo New Car Show).

Dealing with the public is inherently a time consuming activity. Substantial unanticipated time was spent dealing with the public for ACN publicity efforts and maintaining relations with the test participants. Publicity efforts included national network television shows, public meetings, and the production of videotapes. Participant maintenance efforts included managing a participant database, servicing participant questions and problems, dealing with people selling their vehicles or leaving the area for extended periods (especially those that did not inform the FOT operations team), and resolving cellular phone service billing problems.

An additional cause was the time and effort expended on equipment maintenance revision efforts. These efforts were due to unexpected problems encountered after the ACN equipment was fielded. These problems were primarily related to cellular telephone operations. It is possible that these problems might have been discovered before fielding systems to the public (and thus reducing revision costs) if there had been a pilot test of a number of operational systems. The effect of this issue was a financial and manpower drain on members of the FOT team. In addition, some planned evaluation data were not collected due to resource constraints.

While this issue was not resolved for the ACN FOT, it is recommended that future FOTs should carefully consider the costs associated with dealing with the public and with participant recruitment and equipment installation and maintenance when planning their test program In addition, there should be an pilot test period prior to public deployment to allow equipment problems to be discovered and limit revision costs. Another possibility is to use an experienced public relations firm to conduct recruiting and public interface tasks.

5.3.2 PROJECTS WITH MULTIPLE PARTNERS ARE DIFFICULT TO MANAGE

Projects with multiple partners are typically difficult to manage. During the ACN FOT, Veridian Engineering made the observation that constant monitoring of program day-to-day operations was required. The ACN FOT had a large number of partners, including Veridian Engineering, NHTSA, JHU/APL, Erie County Sheriff's Office, ECMC Department of Emergency Medicine, Erie County Department of Emergency Services, State University of New York at Buffalo Industrial Engineering Department, Cellular One, and Rural Metro Medical Services of Western New York. In addition, participants in the FOT included the owners of ACN-equipped vehicles, owners of CET-equipped vehicles, dispatchers at the Erie County Sheriff's Office and other PSAPs in Erie County, equipment installation personnel, and police and EMS personnel in Erie County.

The causes of this issue included the partners being of different types and the loosely defined relationship among some of the test partners, with responsibilities and accountability not firmly defined. The types of partners included those that provided or received funding and thus had direct responsibility for achieving results; public agencies that were not paid but which were motivated by public service; and private companies that were not paid but which were motivated by future market opportunities. Those agencies or companies that were not paid were often unable to place high priority on immediate tasks In addition, the voluntary nature of participation in the FOT resulted in a lack of accountability from test participants.

The effect, as reported by Veridian Engineering, has been to impact the smooth operation of the FOT and require constant pressure on participating parties to ensure that tasks are carried out. This was most often noted in association with participants that were not active partners in the FOT such as the drivers of ACN or CET-equipped vehicles, or the organizations that participated in CET installations. In addition, during periods of low FOT activity, actions one partner assumed were being done by another were not always accomplished without either partner being aware that something was amiss.

Some resolution to this issue has been achieved by scheduling regular FOT team meetings to review all activities underway, and ensuring that these meetings are held in a non-blame seeking environment. Veridian has stated that holding periodic meetings has helped maintain a focus on the goals of the FOT and that the meetings have been productive due to the supportive approach taken and because they have forced the team to organize and methodically share issues and actions. It is recommended that FOTs schedule regular team meetings even during periods of low-test activity and that a project organization that addresses responsibilities and accountability be laid out and agreed to by all participants.

5.3.3 PARTICIPANT COMMITMENT

It was observed that not all participants in the ACN FOT were committed to its goals. Examples noted during the FOT involved the owners of CET-equipped vehicles and the dispatchers at the Erie County Sheriff's Office. It has been hypothesized that a lack of commitment to the FOT by owners of CET-equipped vehicles may have been a factor in the less than expected volume of data collected in the CET portion of the FOT, which relied on participants calling Veridian if they had a crash. Owners of CET-equipped vehicles did not receive any incentives to participate in the FOT and many owners of CET-equipped vehicles were recruited to participate in the FOT based not on an interest in automotive safety, but rather to raise funds for the organizations (e.g., volunteer fire departments, church groups, or school groups) performing the CET installations, which were paid a few dollars per installation. In addition, CETs are mounted out of sight under the hood and the window sticker reminding participants to call Veridian after a crash was small. It is possible that after the stress of being in a crash, participants forgot to call Veridian.

Although the issue of commitment from the owners of CET-equipped vehicles was addressed during the FOT, it was not completely resolved. Veridian tried to maintain interest in and motivation to support the program by periodically sending mailings reminding CET participants about their responsibilities and asking them to call when they sold their vehicle or moved out of the test area. Also, since many CET participants' stickers had the original FOT expiration date, which was later extended, they were informed of the extension and that their continued support was needed. It was noted that managers of future FOT trials that require active support from participants with limited day-to-day involvement and little to gain personally may need to make an effort to periodically remind them about the project and to provide incentives for continued support.

While upper management at the Sheriff's Office had been involved in planning for the ACN FOT and was very supportive of the project, during installation of and training on the central dispatch facility equipment it became apparent that the dispatchers initially had little interest in participating in the ACN project. The cause of this issue appeared to be a lack of involvement by the dispatchers in the planning of the ACN FOT and concerns with the impact that it would have on the dispatchers' workload. It is believed that the dispatchers felt that the system was being imposed on them without considering their inputs.

The dispatchers at the Erie County Sheriff's Office are the actual users of the ACN system at the central dispatch facility. While it was not necessary for them to be supportive of the ACN concept, it was necessary for them to operate the equipment properly and provide unbiased feedback on the operation of the system. If they viewed the ACN FOT as something they "had to do," an effect might have been biased test data. The issue of commitment from the dispatchers at the Erie County Sheriff's Office was addressed by having training sessions with the dispatchers that covered the importance and utility of the ACN system and the minimal impact that it would have on the dispatchers' workload. In addition, Veridian attempted to "involve" the dispatchers in the FOT by frequently stopping by to express appreciation for their support and important contributions, and by building project morale through efforts such as periodically providing pizza for the dispatchers. A lesson learned from this issue was that FOTs should not count on upper level management support as being indicative of desire to participate in the test from the organization's workers, rather obtaining the support of an organization's workers needs to be addressed early in the test program.

5.3.4 DEPENDENCE OF RESULTS ON FOT ARCHITECTURE

The ACN FOT architecture is representative of ACN architectures dialing a 1-800 number to a central dispatch facility for a region. As the CDF in the ACN FOT, the Erie County Sheriff's Office, is a PSAP (and capable of switching calls to other PSAPs in Erie County), it is also somewhat representative of a direct dialed 9-1-1 architecture. However, this FOT did not address changes required to the wireless 9-1-1 system to support a direct dialed 9-1-1 architecture. The architecture choice for the ACN FOT was based on what was technologically feasible and financially affordable for this particular FOT and was not meant to be the architecture choice for future deployed ACN systems.

The purpose of the ACN FOT was to demonstrate the technological feasibility of ACN systems, with a focus on assessing the effect of the ACN system on EMS response times to the extent possible under the constraints of the testing. It was not expected that the choice of ACN FOT architecture would significantly affect the results of this evaluation. It is possible that the reported EMS response times may be shorter than those for an architecture using a 1-800 number that would have to forward all calls to the correct PSAP, and slightly longer than those for a direct dialed 9-1-1 architecture.

5.3.5 SYNCHRONIZATION OF EVENT TIMES

A primary focus of the ACN FOT was to assess the effect of the ACN system on EMS response times. The determination of response times uses the times of events recorded by multiple parties (dispatchers, EMS personnel, police and fire personnel, and test equipment) at multiple locations (crash site, Erie County Sheriff's Office, and PSAPs). To produce accurate response times requires that the time sources at these multiple locations be synchronized (or the time offsets be known) and that the humans involved record the time of the event accurately when it occurs.

The cause of this issue was the potential for inaccurate recording of times by participants and unknown offsets between the times recorded by the participants at different locations, particularly for the CET baseline response time analysis. This issue is illustrated by anomalies in the test data such as when a PSAP is notified of a crash prior to the time of the crash, but may also result in non-obvious biases to the results. The ACN FOT attempted to cost-effectively resolve this issue by educating the participants on the importance of accurate time entry and by collecting time offset data for the Erie County Sheriff's Office and PSAPs. It is recommended that future EMS response time analyses develop improved methods for ensuring that the times of events are accurately recorded.

5.3.6 PAUCITY OF ACN EVENTS

ACN events were rare for the dispatch personnel participating in the FOT, who could go for long periods without handling an ACN call. Only about 15 to 30 crash events were expected during the ACN FOT. An effect of this issue could have been reduced familiarity with the ACN equipment and associated procedures, which could result in a bias to the response times observed during the FOT. This issue was raised based on observations that the Erie County Sheriff's Office did not follow the expected procedures for an early ACN event and that the ACN workstation at the Erie County Sheriff's Office had been turned off on another occasion.

To resolve this issue Veridian Engineering instituted a series of unannounced test events to provide operational familiarity with the equipment to the dispatchers at the Erie County Sheriff's Office. In addition, Veridian Engineering issued notices after all ACN events to the operators not on duty to keep them familiar with the operation of the system. It is not expected that a lack of crashes will be a factor in operational deployments of ACN systems.

5.3.7 NOTIFICATION OF CET CRASHES

The number of crashes of CET-equipped vehicles during the ACN FOT was lower than expected based on historical crash statistics. This may have been caused at least in part by owners of CET-equipped vehicles not reporting crashes involving their vehicles to Veridian Engineering. It should be noted that the reporting of crashes of CET-equipped vehicles relied either on the owner of the vehicle calling Veridian Engineering; or on police, EMS personnel, or repair shop personnel noticing the small CET sticker and calling the provided 1-800 number.

The effect of non-notification of CET crashes was to reduce the data available for determining an EMS response time baseline. Possible reasons for non-notifications of crashes by CET-equipped vehicles included forgetfulness by the vehicle owners, a reluctance to report crashes when the owner of the vehicle is at fault, and a lack of commitment to the ACN FOT by owners of CET-equipped vehicles. Factors contributing to driver forgetfulness include the fact that the CET is mounted under the hood on the firewall of the vehicle and the window sticker is not always noticed after vehicle owners get used to seeing it there. In addition, the people involved in crashes can be expected to be under some stress following the crash (e.g., dealing with injury and pain, planning for vehicle repairs, and worrying about expenses that will be incurred and appointments missed).

This issue was not resolved for the ACN FOT. It is recommended that any future efforts to determine EMS response time baselines consider incentives to encourage the reporting of crashes or other means of crash notification, including those that do not require reporting by the owners of the CET-equipped vehicles. Veridian has reported developing an improved procedure for collecting CET-data that involves receiving police reports on crashes every two weeks and checking the license numbers against the participant database.

5.3.8 DRIVER DENIAL OF A CRASH EVENT

It was expected that for some of the ACN messages received at the central dispatch facility, the drivers would either report that there was no crash and that emergency services help should not be sent or that the drivers would not reply to the voice call and would leave the scene of the reported crash. This might be caused by a false notification message, a minor crash for which the driver does not want to be delayed while waiting for emergency services to respond, or the desire of the driver to not be present when emergency services or law enforcement personnel reach the scene of the reported crash.

The possible effects of this issue include: (1) an inability to correctly determine cases of false notification, (2) a lack of trust in the system by emergency services personnel, and (3) vehicle owners may be reluctant to install an ACN System if they must wait for emergency services personnel after false notifications or minor collisions, or if they will be followed home by law enforcement personnel after leaving the scene of a reported collision.

The ACN FOT expected participants to remain at the scene of a reported crash. Participants were asked to provide this support to the test as a condition for participation. If vehicles did not remain at the scene or if the occupants indicated a desire to leave, the following procedures were to be used: (1) occupants would be instructed to stay at the scene, (2) the Sheriff's Office would call back the vehicle on the cellular phone if the connection was lost, (3) the vehicle location would be sent to Veridian Engineering later with the supplemental data from the crash, and (4) the Sheriff's Office would make a call to the participant's home if necessary.

While this issue did not occur during the ACN FOT, it will apply to future ACN deployments. Although the inability to correctly determine cases of false notification will not be a concern of an operational system, the potential for a lack of trust in the system by emergency services personnel due to calls for which the vehicle leaves the scene of the crash will. In addition, there may be reluctance by some drivers to install an ACN System in their cars if emergency services and law enforcement officials are automatically dispatched. A possible solution to these issues for a private service provider is to only automatically dispatch when they are unable to contact the vehicle; the driver would be allowed to cancel an automatic activation. It is unlikely that this solution could be implemented if the call is made directly to a PSAP.

5 3.9 CONFIDENTIALITY OF MEDICAL RECORDS

While the ultimate measure of the benefit of an ACN system is the reduction in mortality and morbidity of motor vehicle crash victims, the evaluation of system benefits in the ACN FOT focused on quantifying the reduction in EMS response times possible with an ACN system. This focus was chosen, as the limited number of crashes expected to occur in the ACN-equipped vehicle population during the test period would preclude a statistically meaningful analysis of mortality and morbidity of crash victims. Nevertheless, during the test, information was to be collected on the injury severity and mortality of the crash victims from their case histories and other information provided by the emergency room doctors and/or trauma surgeons. This information was to be reviewed to determine if there was any indication of the ACN system contributing to the probability of a positive medical outcome for the crash victim.

There was a concern that confidentiality requirements imposed on medical records might make it difficult to collect this information and thus conduct any review of the medical outcomes for the crash victims. This issue was overcome for the ACN FOT by working closely with the staff of the ECMC Department of Emergency Medicine to obtain the necessary medical records, although this process of obtaining the records did not always go smoothly. While this issue will not apply to future ACN deployments, it is applicable to future operational tests or analyses concerned with the medical outcome of participants. It is recommended that the issue of obtaining medical records be adequately addressed during the planning stage of any future operational tests or analyses concerned with the medical outcomes of participants.

Section 6

SOCIETAL BENEFITS

6.1 INTRODUCTION

The single, directly measurable societal benefit that ACN systems offer is the reduction in time between a motor vehicle collision and the arrival of emergency medical assistance. Therefore, to understand the benefits to society that this capability conveys, the following approach was taken. First, the times involved in the medical response to a vehicle crash were classified and analyzed to determine the specific quantitative effects the ACN system might have. Next, the medical nature of injuries and fatalities suffered during motor vehicle crashes was investigated to begin to establish a qualitative time dependence of trauma. Then, based on studies found in medical publications, the potential for injury and fatality reduction by an ACN system was estimated. Finally, the medical benefits imparted by the ACN system were translated into approximate dollar figures.

6.2 TIMES INVOLVED IN MOTOR VEHICLE COLLISION RESPONSE

The time between crash occurrence (assumed to be the moment of injury) and the delivery of the victim to a medical facility can be divided into three periods: notification time, dispatch time, and transit time. The notification time covers the time required to notify emergency response personnel of the crash, the dispatch time is the time required to dispatch the EMS team, and the transit time includes the time to travel to the scene, administer aid, and transport the victim to a medical facility. Further separation of these groups into smaller, sequential divisions of the categories offers insights into the possible system benefits. The following seven divisions were created: decision period, contact period, call period, dispatch period, response period, aid period, and transport period.

The notification time is divided into decision, contact, and call periods. The decision period begins with the moment of injury and ends when the driver, a passenger, or a witness realizes that professional medical aid is required. This period varies greatly and can be dependent on a number of factors including time of day, population density, traffic density, and random chance. A police car passing by a remote collision by chance would significantly alter the decision period. Any crash that renders the vehicle's occupants unconscious or unable to coherently respond to the situation can result in a drastically increased decision period. For all practical purposes, this period is eliminated by the presence of an ACN system.

From the time the decision is made to notify the proper authorities to the time that a landline telephone, cellular telephone, or other communications equipment needed can be located composes the contact period. The availability of equipment is again dependent on the population and traffic density, time of day, and general prosperity of the region. If the collision occurs in a relatively urban or suburban environment, a telephone is seldom far away. In a rural environment, locating the necessary equipment can be problematic. This period is also effectively eliminated by the presence of an ACN system (given that there is cellular telephone coverage at the crash site).

The length of time that the actual process of contacting emergency medical response personnel consumes is known as the call period. This period is the last subdivision of the notification time and is usually negligible, less than a minute, unless there is some form of miscommunication between the operator and the crash survivor or witness. Typical reasons for this would include a language barrier or if the survivor is unaware of the magnitude of the injury. The ACN data message eliminates the possibility of a miscommunication concerning the vehicle location or the severity of the crash, and the opening of the voice link facilitates direct transfer of information between the EMS dispatcher and the crash victim.

The single division of dispatch time is the dispatch period. This is the time between the notification of a motor vehicle crash requiring medical assistance and an emergency medical team being dispatched. Recent studies have shown this delay to be approximately a minute in length (Reference 16).

The last major delay for crash victims to receive medical assistance occurs during the transit time. The transit time is divided into response, aid, and transport periods. It encompasses the time it takes the EMS team to travel to the crash scene (response period), administer the initial medical aid (aid period), and then transport the patients to the emergency medical facilities (transport period). These periods, combined as one for the sake of brevity, are highly variable and many debates have occurred as to their effect. The response period could conceivably be shortened by the knowledge of the exact crash location, as provided by the ACN system. While the other two time components will usually be unaffected by the ACN, the information provided on crash specifics could be useful in determining the type of medical response unit to dispatch (e.g , report of severe trauma could suggest helicopter transport would be required).

Very little data are available describing the distributions of these periods due to the lack of appropriate record keeping and errors in such data. The precise time of the crash is often unknown. Thus, a priori, the data will have an error associated with this uncertainty. Compounding this problem, Baker (Reference 3) found that the actual time of the crash, when known, is often rounded to the nearest multiple of five minutes. A study by Brodsky (Reference 17) in Missouri found that 67% of urban and 91% of rural emergency calls were rounded. However, the study found that there was no tendency for the calls to be rounded up or down. The implication of this result is that, although there are uncertainties in estimates of the crash times, no systematic bias is expected in the existing data.

An ACN system, when fully functional, should minimize the notification time (comprising the decision, contact and call periods), but, in most cases, should not greatly affect the other times. Recently, some effort has gone into studying the notification time distribution for crashes in the state of Missouri (Reference 17), which was chosen for the similarity that its urban and rural environments have to many other Midwestern states. Using nonfatal crash data from 1987 and fatal crash data from 1985-1988, Brodsky found a distinct difference in response times for urban and rural locations. In urban areas, 20% of calls were received in less than a minute after the collision, 70% of calls came in under 5 minutes, and only 6% took more than 10 minutes. In stark contrast, in rural areas only 5% of calls came in under a minute, 34% of calls came in less than 5 minutes after the crash, and 34% of calls took more than 10 minutes. During the late night hours, from 11 p.m. to 7 a.m., the probability of a call for help coming more than 10 minutes after the collision was found to double in both the urban and rural environments. Thus, the ACN system could significantly reduce the amount of time between the collision and arrival of medical aid for a sizeable number of vehicle crashes, in the circumstances that most require it, rural and late-night collisions. The next logical question is whether this time saving will significantly benefit the victims of these crashes.

6.3 MEDICAL ASPECTS OF CRASH INJURIES AND FATALITIES

This section examines the medical nature of injuries and fatalities suffered during motor vehicle crashes. It first reviews the types of trauma that occur for different crash types. Then, it looks at the mechanisms of death and the time dependence of trauma.

6 3 1 TRAUMA INJURIES

Trauma injuries stem from either penetrating or blunt forces, with penetrating injuries requiring much less force. The majority of crash-related medical injuries involve blunt trauma originating in the three types of impacts, which occur during a collision. The first impact involves the motor vehicle colliding with another object (car, tree, guard rail, etc.). The second impact results from the occupant hitting different structures within the vehicle and rebounding into additional objects after initial strikes within the passenger compartment. The final impact is internal to the occupant's body and results from the differential movement and acceleration of fixed physiologic structures versus more mobile or flexible tissues. Thus, victims of crashes often sustain multiple trauma injuries. Reference 18 provides the average annual number of injuries to all vehicle occupants involved in a crash for the years 1994 through 1996. There were 240,000 head injuries and nearly 200,000 chest and abdominal injuries per year during this period. Looked at another way, there were nearly 250,000 injuries per year, which were classified as AIS-3 or higher. Outcomes for these types of injuries may be the most affected by a reduction in EMS response times.

The pattern of injury in a motor vehicle crash depends primarily on the following parameters-

a. Vehicle Size

b. Vehicle Speed

c. Type of Impact

  (1) Frontal

  (2) Rear

  (3) Lateral

  (4) Roll Over

d. Location of Victim

  (1) Driver's Side

(2) Passenger's Side

e. Proper Use or Deployment of Restraining Devices

(1) Lap Belt

(2) Shoulder Belt

(3) Air Bag.

The first two parameters, vehicle size and vehicle speed, can affect the severity of the injury but do not aid in the categorization of injury type. The last three factors may be used to characterize the typical patterns of injury seen in motor vehicle crashes (Reference 19).

A frontal crash arises when the motor vehicle impacts a stationary object or another motor vehicle while travelling forward or by being impacted from the front while stationary. The properly restrained driver may experience trauma from the restraint mechanisms. The lap belt may cause fractures to the lower (lumbar region) spine, pulmonary or cardiac contusions, and injury to the bowels including a torn or ruptured spleen, liver, kidney, or pancreas. The unrestrained driver faces serious injury due to possible collision with the steering wheel, windshield, dashboard, A-column, and/or floorboards. These impacts can result in the following types of injuries (Reference 20) (the percentages represent percent of crash unrestrained drivers experiencing the injury):

a.	Cranial injuries	16%
b.	Facial bone fractures	37%
c.	Cervical spine injuries	10-15%
d	Major thoracic injury	46%
e.	Abdominal injury	5-10%
f.	Distal lower extremity fracture	33%
g.	Pelvic fractures	46%
h.	Femur fractures	65%
i.	Forearm fractures	46%

The properly restrained front passenger experiences the same injury types as the driver. Because of the lack of a steering column, the unrestrained front passenger typically undergoes more upward rotation than the unrestrained driver does. This results in more injuries sustained to the cranium and to the face.

A lateral crash occurs when another motor vehicle impacts the side of the car or the motor vehicle slides sideways into a stationary object. The unrestrained driver can suffer numerous head injuries, fractures to the cervical region of the spine, fractures of the rib, pulmonary contusions, lacerations of the spleen, and lateral compression fractures of the pelvis (Reference 20). The unrestrained front passenger may suffer injuries very similar to the driver but the liver will be affected as opposed to the spleen.

A rear impact results when the motor vehicle backs into another vehicle or a stationary object, or when struck from behind by another motor vehicle. Rear crashes cause 8% of serious injuries (Reference 19). Whiplash, the extension and flexion of the neck and spine, is the most common injury.

In a rollover impact, much of the vehicle's kinetic energy is dissipated over time and space with each revolution of the car If the passengers are properly restrained and the vehicle's cabin maintains its structural integrity, this gradual dampening of energy and subsequent impulse typically limits the amount of injury. However, if any of the passengers are unrestrained, the injuries can be quite severe and are usually random (Reference 19)

6 3.2 MECHANISMS OF DEATH

If the trauma from a crash is severe enough, death can occur. Every physiological system of the body ultimately functions to keep the brain alive. Death results if one of these systems fails to the extent that the brain is damaged or completely destroyed. With the energy levels involved in a car crash, total mechanical destruction of the brain is possible, but rare The most common and the quickest physiological failure that can occur is disruption in the delivery of oxygen to the tissues of the brain. Brain death occurs within several minutes without oxygen. Generally, failure of the respiratory or circulatory system is to blame. More specifically, this lack of oxygen may occur as a result of several possible mechanisms. These include massive loss of blood, heart attack or failure, large obstruction of the air way, pneumothorax (resulting from puncture and subsequent collapse of a lung), or destruction of the major conduits delivering blood to the head.

6.3.3 TIME DEPENDENCE OF TRAUMA

The time dependence of trauma is commonly accepted. For example, Reference 21 states for traumatic brain injury, "All neurological damage does not occur at the moment of impact (primary injury), but rather evolves over the ensuing minutes, hours, and days. This secondary brain injury can result in increased mortality and more disabling injuries." What remains in question is the exact quantification of this variable. Contemporary literature in this field (References 20 - 24) often refers to a "golden hour" where the first 60 minutes of care after a multiple trauma injury is described as "crucial." Furthermore, within this first hour, care seeking to correct the underlying problem causing the patient's condition to worsen must be administered. This type of care can best be administered in a suitable facility such as an emergency room or, even better, a dedicated trauma center. Thus, transport of the victim to such a facility needs to be accomplished within this time frame. Administration of fluids and other simple, supportive care treatments, while not enough in critical situations, should be started within the "Golden Ten Minutes" (Reference 25). This offers a loose bound of 10 minutes on the time from the occurrence of the motor vehicle crash to the arrival of medical aid in severe cases.

To further elucidate the time dependence of trauma, several studies have been conducted to show the distribution of fatalities over time after the occurrence of trauma. In what is now a relatively well-known article (Reference 26), Donald Trunkey discovered a tri-modal fatality distribution in 862 urban trauma deaths over a 2-year period at the San Francisco General Hospital nearly 20 years ago. The first group, the "immediate deaths," died less than an hour after the trauma from lacerations of the brain, brain stem, spinal cord, heart, or a major blood vessel. Trunkey considered only a very few of these fatalities preventable. The bulk of the time dependent, preventable fatalities were in the second group known as "early deaths." Deaths in this category occurred one to three hours after the trauma and were caused by major internal hemorrhage or multiple organ injuries. The deaths recorded several days to weeks after the precipitating event, the "late deaths," were often caused by multiple organ failure and were characterized by less time-dependence than deaths in the first two categories. Overall, "immediate deaths" represented 45% of the trauma victims. "Early deaths" composed roughly 30% of the victims with the remainder falling into the "late death" category. More recent studies have shown that improved trauma care and support has modified this tri-modal distribution Both a study in Denver, Colorado, in 1992 and one in Pima County, Arizona found that the tri-modal distribution of deaths had been smoothed out considerably with less distinct or fewer peaks (References 27 and 28).

The change in the time distribution of deaths resulting from trauma is significant due to the likely causes of these changes. The "early deaths" peak likely has been reduced due to a better understanding of trauma and improved facilities and thus more quickly administered medical aid. A study reported in 1998 in Portland, Oregon (Reference 29) further bolsters the importance of the time-dependence of trauma. The researchers found, after examining 848 trauma cases, that the response time was significantly shorter (3.5 ± 1 2 minutes) for unexpected survivors compared to unexpected fatalities (5 4 ± 4.3 minutes). Simply put, a shorter response time resulted in a greater likelihood of survival.

Due to the lack of relevant, contemporary research, indirect evidence was found and explored to begin to quantify the relationship between time and trauma. In the last 15 years, several studies have been performed to determine the benefits for the air transport of trauma victims. The net effect of air transport is to reduce the time between injury and medical care. Ninety percent of the population in West Germany is within 15 minutes of a Level 1 trauma center by means of ground or helicopter transport resulting in a 25% decrease in motor vehicle mortality (Reference 26). In other regions, rotor wing aircraft have caused a drop as high as 52% in fatalities (Reference 30). Thus, even though not all patients can be transported by air to the necessary facilities, air transport has caused a decrease in motor vehicle collision fatalities by reducing the time for definitive medical care to be administered.

6 4 MEDICAL BENEFITS OF AN ACN SYSTEM

A qualitative analysis of some published results highlights one of the benefits offered by ACN. Geographically, fatality rates from motor vehicle collisions are greatest in areas with the lowest population densities Nearly 60% of fatal crashes occurred in rural regions (Reference 17). For example, Esmerelda County in Nevada with 0.2 residents per square mile has a collision fatality rate of 558 per 100,000 people. In stark contrast, only 2.5 people per 100,000 die from crashes in Manhattan, New York with a population density of 64,000 per square mile. There are many factors involved with this phenomenon such as higher rates of travel, low usage of seat belts and other safety devices, prevalence of high risk vehicles such as trucks and sport utility vehicles, worse roads, distance between hospitals, and reduced access to trauma centers (Reference 3). And rural areas have the greatest EMS notification times (Reference 17). Additionally, longer notification times are often coupled with longer driving times for ambulances and fewer trauma centers and more remote hospitals. Thus, the ACN system would offer the greatest medical benefit in rural areas, the regions that need it the most

An ACN system should reduce the length of time between traumas and needed restorative medical care. Extrapolating from the findings of air transport fatality reduction studies (References 30 and 31), the ACN system could offer an approximate 20% reduction in fatalities from motor vehicle collisions. This estimate assumes that adequate medical facilities would be available. Unfortunately, no studies have been found to assess the time dependence of injury severity caused by motor vehicle trauma. Thus, any estimate of the affect of ACN on reducing injury severity would be little more than a guess. This area requires further study. However, an NHTSA-sponsored multidisciplinary research team has produced a computer program (References 2, 4, and 5) which attempts to produce an easily understood probability of serious injury estimate making use of data which would be available from an ACN system.

6 5 FINANCIAL BENEFITS OF AN ACN SYSTEM

In 1988, 47 thousand fatalities resulted from the nearly 5 million people injured in collisions involving motor vehicles. In 1997, 42 thousand fatalities resulted from motor vehicle collisions. The costs of these fatalities and injuries has been calculated to be extremely high, partly due to the average years of expected life span remaining for the survivors. In 1988, it was estimated that people injured from motor vehicle crashes averaged 47 years of life span left. During this same year, people killed in motor vehicle crashes were projected to have an average of 43 years of life span left. To calculate the cost that this incurred to society, the following factors were taken into consideration:

a medical care

b. emergency services required

c. lost income and household productivity

d. disruptions to the workplace

e insurance administration

f. legal proceedings and their costs

g. lost quality of life.

Together, the sum of these expenses represents the comprehensive costs of motor vehicle crashes. In 1988, an estimate was made that the 47 thousand fatalities cost $112 billion dollars and the 4 833 million injuries cost $178 billion dollars (Reference 32). By 1994 the number of fatalities had fallen to fewer than 41 thousand costing $116 billion dollars, while the number of injuries rose to 5.278 million at a cost of $219 billion dollars (Reference 33 and 34).

To compute the possible cost savings that could result due to an ACN system, several assumptions need to be made. The dollar amounts shown in the preceding paragraph have to be averaged over the number of people injured or killed. This assumes that each person injured or killed caused an equivalent financial loss, or, that the inexpensive ones exactly balance the expensive cases. Next, it is assumed that the total number of people killed or injured would remain the same. Although there could be a substantial reduction in the number of people injured due to the ACN, this is not taken into account. Thus, if usage of the ACN system reduced the number of fatalities, the number injured would increase by approximately the same amount. Those who originally would have been fatalities but survive due to earlier medical intervention might be considered to become injured at the "average" financial level. Although this may seem counterintuitive at first, two factors support this assumption. First, neurological traumas in automobile crashes can result in severe and expensive permanent disabilities. However, many of the fatalities caused by severe neurological trauma would be virtually impossible to prevent. Secondly, those people who could be saved by earlier medical intervention often die from loss of blood or difficulties breathing. If these injuries can be stabilized, many times a full recovery can be expected as opposed to an extremely expensive and permanent handicap.

Although a large percentage of the fatalities in motor vehicle crashes may not be preventable, a quicker emergency medical response time could also benefit organ transplants Recent statistics have indicated that six people die every day in America waiting for an organ transplant. Additionally, 80% of the patients with end stage organ failure could be saved with a transplant (Reference 35). Arriving on the scene of a crash quicker would allow a greater probability of successfully obtaining organs for transplants. However, the direct impact the quicker response would have on organ transplants is very difficult to quantify. The energetic nature of motor vehicle crashes often renders many needed organs unsuitable for transplant purposes. Further research is needed for this area of inquiry.

Section 7

OBSERVATIONS

7 1 GENERAL

The development and deployment of ACN systems is technically feasible. This was demonstrated in the ACN FOT and is supported by current activity in the commercial marketplace. The potential benefits of an ACN system would result from reduced PSAP notification times, improved knowledge of the vehicle location, and estimates of crash severity and the probability of serious injury.

Since the ACN FOT was initiated in 1995, commercial crash notification services have entered the marketplace. The first were offered in 1996 and based notification on air bag deployment or manual activation, thus limiting the types of crashes for which automatic notification is possible. The crash notification message in these systems is delivered to a private response center via cellular telephone. The response center then establishes a voice connection to the appropriate PSAP for EMS dispatch based on the vehicle's location and relays the information in the data message. Future versions of these systems could use accelerometers (or other sensors) dedicated to the ACN function similar to those used in the FOT, allowing a greater variety of crashes to be automatically detected and potentially providing estimates of crash severity and the probability of serious injury.

These commercial crash notification systems utilize private response networks, as the 9-1-1 system does not currently allow ACN calls to be delivered directly to a PSAP by dialing 9-1-1. It should be noted that this process of going through a private response center, instead of directly to a PSAP via 9-1-1 lines, may increase the response time as well as provide an opportunity for the introduction of errors into the crash information. The National Mayday Readiness Initiative, a public-private partnership of more than 30 national organizations, co-sponsored by the U.S. Department of Transportation (DOT) and the ComCare Alliance, is attempting to address the issues that arise in dealings between private response centers and PSAPs, including the routing of ACN calls into the 9-1-1 network and the transfer of data messages.

These private response networks will continue to exist at least until a nationwide ACN public response network is deployed, and given the need for public infrastructure development and deployment, that is likely to occur over an extended period As multiple commercial ACN systems are deployed and an eventual public ACN system developed, there will be a need for compatibility with the public infrastructure and standardization of communications protocols and crash notification messages to allow for interoperability between systems and equipment. In addition, institutional issues such as liability when an ACN does not work as intended or privacy issues associated with ACN data and its collection need to be resolved. The remainder of this section will present the most important system performance results from the ACN FOT and the most significant institutional issues that were encountered.

7.2 SYSTEM PERFORMANCE

The data sample available for analysis from this FOT was considered to be too small to enable significant conclusions to be drawn. There were only 15 ACN crashes available for analysis of PSAP notification times, and the number of samples available for other EMS response times was even smaller. The sample size for the baseline response time data collection effort was also extremely small. There were only 25 CET notification times available for analysis. Nevertheless, it can be stated that the ACN system worked as expected. The CDF at the Erie County Sheriff's Office was successfully notified in 16 of the 21 ACN crashes for a success rate of 0.76. The five failures were due to: (1) insufficient cellular phone coverage at the crash location, (2) damage inflicted to the ACN in-vehicle system during the crash, (3) low vehicle battery voltage when the backup battery was not available due to corroded terminals, (4) a disconnected telephone line to the modem in the ACN dispatch center equipment at the Erie County Sheriff's Office, and (5) unknown causes. The ACN system success rate would improve to 0.80 if the anomalous failure due to the disconnected telephone line is removed form the test sample.

The ACN system notified the CDF within 2 minutes of the reported crashes and it was noted that after the CDF computer was synchronized to a standard time source partway through the FOT, all notifications were within 1 minute. This performance was consistent with what was expected for the system. The average baseline notification time from the CET evaluation was 5.6 minutes. While the majority of the CET notifications were within 3 minutes, the distribution of CET notification times included a number of larger times (9, 12, 30, and 46 minute times were included in the limited test sample).

There were 31 false notifications made to the CDF for a non-crash event during the FOT. Veridian Engineering attributed these false alarms to faulty accelerometer mounting in the in-vehicle system or unstable or intermittent power supplied to the in-vehicle system. This number of false alarms would most certainly result in a false alarm rate considered unacceptable in a system with widespread deployment. However, it is likely that improvements in the production process and hardware design could significantly reduce the false alarm rate from that experienced in the developmental equipment used in this FOT.

In summary, it can be stated that:

a. The ACN in-vehicle system worked as expected. It was able to sense that a crash had occurred, determine the vehicle's position, and deliver a crash notification message to the FOT 9-1-1 dispatch center via a cellular telephone call that was then switched to a voice line.

b. The crash detection algorithm detected all but one injury crash during the FOT (an AIS-1) and reduced the notification of property damage-only crashes by more than 85%.

c. The ACN system produced an average PSAP notification time of less than 1 minute. This average notification time was significantly less than the observed times for a number of the CET crashes.

d. The ACN system success rate was in the range of 0.76 to 0.80 Failure mechanisms included expected cases of insufficient cellular phone coverage at the crash location and damage inflicted to the ACN in-vehicle system during the crash. It should be noted that the small data sample size for the FOT limits the statistical significance of this result.

e. The ACN in-vehicle system produced an unacceptable number of false alarms during the FOT; however, it is likely that improvement in the production process and hardware design could significantly reduce the false alarm rate from that experienced in the developmental equipment used in this FOT. A need for improving the reliability of the developmental ACN dispatch center equipment was also noted during the FOT.

7.3 INSTITUTIONAL ISSUES

Two types of institutional issues were encountered during the ACN FOT - those that could impact the development and deployment of ACN systems and those that either impacted or had the potential to impact the conduct of the FOT. The most significant of these two types of issues will be discussed below.

7.3.1 ACN SYSTEM ISSUES

Major institutional issues were noted during the ACN FOT that could impact the development and deployment of ACN systems:

a. ACN system liability

b. Access to ACN data

c. Ability of drivers to understand the ACN technology.

The first two ACN system issues were raised during the planning phase of the FOT. As the ACN FOT system was an experimental prototype; there were concerns raised over potential liability if the ACN system failed to work or if help was not provided in time to injured participants. The cause for this issue was the litigious society that we live in; the legal foundations for these concerns were not addressed The second potential issue was based on the fact that the ACN system for the FOT collected data that could provide information concerning collisions and the operation of the vehicle (e.g., position, velocity, heading, and acceleration). There was a concern that the data collected during the FOT would be subpoenaed during litigation involving ACN-equipped vehicles in an attempt to establish fault in a crash.

While neither of these issues arose during the FOT, they remain potential concerns for future ACN deployments. Actions taken during the FOT in response to these concerns included designing the ACN System to be safe and reliable and to not change the way emergency responders deal with highway emergencies. In addition, Veridian Engineering developed a Disclosure and Warning Statement and Waiver using proper legal terminology to be signed by owners of ACN-equipped vehicles and a witness. The disclosure and warning statement noted that the ACN system was an experimental system and there could be instances where this experimental system fails or does not perform to expectations. The waiver also granted Veridian Engineering the right to use any and all data gathered from the FOT, with the exception of revealing the participant's identity or personal information to persons other than the participants in the program.

Other approaches to mitigating liability for ACN systems noted during the project include the development of accepted operating standards, dispatcher and notification center certification standards, and accepted procedures and protocols for interfacing and coordinating between private and public emergency response systems. It is also recommended that as requests for ACN data are to be expected, the architecture of future ACN systems should either support the provision of this information, or the ACN systems should not collect or save data that could be used against drivers. In the former case, the recruitment/sales literature should state the information that is available and the policies and procedures for the provision of this information. This issue will need to be resolved, not only for ACN applications, but also for many other ITS applications.

It was also noted during the ACN FOT that some owners of ACN-equipped vehicles had difficulty understanding how the system operated and the types of crashes for which an ACN response would be generated. It is suggested that future ACN deployments generate improved operating instructions and attempt to better educate the public about the capabilities of ACN systems and how they operate. In addition, other possible methods for resolution of this issue include adding an indicator to the in-vehicle ACN equipment to indicate that a crash has been sensed but that no emergency call is being placed due to the low likelihood of injury, and adding a single-button, manual crash-reporting capability to the ACN system.

7.3.2 FOT ISSUES

Major institutional issues were noted during the ACN FOT that either impacted or had the potential to impact the conduct of the FOT:

a. Required resources were underestimated

b. Paucity of ACN events

c. Notification of CET crashes

d. Participant commitment

e. Synchronization of event times.

The resources (time, money, and level of effort) required to conduct the FOT were underestimated. Areas of underestimation included the time and effort required for recruitment of participants and the installation of ACN and CET equipment, public relations and interacting with the public, and equipment maintenance revision efforts. In particular, the original FOT plans considered the recruitment of participants and the installation of ACN and CET equipment to be short-term efforts that could easily be accomplished. However, participant recruitment and equipment installation turned out to be ongoing activities that required significantly more effort than expected. Also, the data collection period of the FOT was originally to have been a 1-year effort; however, data collection occurred over a 4-year period for the CET portion of the FOT and a 3-year period for the ACN portion. This was both a result of and a symptom of the underestimation of the resources required to conduct the FOT.

An additional drain on resources was the time and effort expended on equipment maintenance and revision efforts. These efforts were due to unexpected problems encountered after the ACN equipment was fielded, primarily related to cellular telephone operations. It is possible that these problems might have been discovered before fielding systems to the public if there had been an extended field test of a small number of operational systems. As a result of resource constraints, some planned evaluation data (primarily related to reliability measures of performance) were not available. Future FOTs should carefully consider the costs associated with dealing with the public and with participant recruitment and equipment installation and maintenance when planning their test program. In addition, there should be an extended small-scale field test period prior to public deployment to allow equipment problems to be discovered and limit revision costs

As noted previously, the data sample available for analysis from this FOT was considered to be too small to enable significant conclusions to be drawn for both the ACN and CET portions of the FOT. While a small number of data samples had always been expected for the ACN portion of the FOT, the actual number of ACN crashes fell at the lower number of expected crashes. A possible explanation for this is that the process for selecting ACN participants, which included the ability to pass a credit check, biased the sample toward more responsible drivers. The pre-test survey indicated that the test driver sample was overweighed towards the middle-to-upper end of the age spectrum and that the drivers were interested in safety. This experience should be considered in the design of future FOTs.

The number of CET crashes was also lower than expected based on historical crash statistics. The test methodology for the CET portion of the FOT relied primarily on the owner of the vehicle calling Veridian Engineering to report a crash. The small data sample for CET crashes was caused at least in part by owners of CET-equipped vehicles not reporting crashes involving their vehicles to Veridian Engineering. Possible reasons for non-notifications of crashes by CET-equipped vehicles included a lack of commitment to the ACN FOT by owners of CET-equipped vehicles, forgetfulness by the vehicle owners, and reluctance to report crashes when the owner of the vehicle is at fault.

The lack of CET-participant commitment to the FOT may have been due to many owners of CET-equipped vehicles being recruited to participate in the FOT to raise funds for the organization doing the installations rather than based on an interest in automotive safety. In addition, the extension of the FOT to a greater than 3-year period vice the original 1-year period may have been a factor in the apparent dropping out of test participants during the FOT. This might have been caused by a lost of interest in the FOT, forgetting that there was an FOT, and changes in ownership of the vehicles over the extended period of the test. It is recommended that any future efforts to determine EMS response time baselines consider incentives to encourage the reporting of crashes or other means of crash notification, including those that do not require reporting by the owners of the CET-equipped vehicles.

It should also be noted that there was an apparent lack of commitment to the FOT from the dispatchers at the CDF despite the support of upper level management at the Sheriff's Office. This was observed during installation of and training on the CDF equipment, and was noted in the surveys completed by the dispatchers. The cause of this issue appeared to be a lack of involvement by the dispatchers in the planning of the FOT and concerns with the impact that it would have on their workload. It is believed that the dispatchers felt that the system was being imposed on them without considering their inputs. A lesson learned was that FOTs should not count on upper level management support as being indicative of desire to participate in the test from the organization's workers, and that obtaining the support of an organization's workers needs to be addressed early in the test program.

A primary focus of the ACN FOT was to assess the effect of the ACN system on EMS response times, which required the collection of accurate time data during the FOT. The determination of response times uses the times of events recorded by multiple parties (dispatchers, EMS personnel, police, and test equipment) at multiple locations (crash site, Erie County Sheriff's Office, and PSAPs). To produce accurate response times requires that the time sources at these multiple locations be synchronized (or the time offsets be known) and that the humans involved record the time of the event accurately when it occurs (as opposed to rounding the time off to 5- or 15-minute intervals). This issue can result in anomalies in the test data such as when a PSAP is notified of a crash prior to the time of the crash, but may also result in non-obvious biases to the results. The ACN FOT attempted to cost-effectively resolve this issue by educating the participants on the importance of accurate time entry and by collecting time offset data for the Erie County Sheriff's Office and PSAPs. It is recommended that future EMS response time analyses develop improved methods for ensuring that the times of events are accurately recorded.

Appendix A

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Appendix B

LIST OF ACRONYMS AND ABBREVIATIONS

ACN	Automated Collision Notification
AIS	Abbreviated Injury Scale
CD	Central Dispatch
CDF	Central Dispatch Facility
CDFE	CDF Equipment
CET	Collision Event Timer
DGPS	Differential GPS
DMV	Department of Motor Vehicles
DOT	Department of Transportation
ECMC	Erie County Medical Center
EMS	Emergency Medical Services
FARS	Fatality Analysis Reporting System
FCC	Federal Communications Commission
FOT	Field Operational Test
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
IVM	In-Vehicle Module
JHU/APL	The Johns Hopkins University Applied Physics Laboratory
MERS	Medical Emergency Radio System

MOE	Measure of Effectiveness
MOP	Measure of Performance
NASS	National Automotive Sampling System
NHTSA	National Highway Traffic Safety Administration
PAR	Police Accident Report
PPS	Precise Positioning Service
PSAP	Public Safety Answering Point
SAE	Society of Automotive Engineers
SPS	Standard Positioning Service
US	United States

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