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PILOT TESTS OF AUTOMATED SPEED ENFORCEMENT DEVICES AND PROCEDURES

Robert R. Blackburn
William D. Glauz

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

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16. Abstract

This report concerns the identification of technologies applicable to speed enforcement and an assessment of their potential utility in the United States. The study emphasizes technologies in common use in Europe and elsewhere, but relatively unknown in the United States. The most common non-United States technology utilizes Doppler radar aimed diagonally across the road, rather than down the road as is the case with American systems, giving it a number of technical advantages. This, and several other technologies identified, can be used with a camera to obtain photographic evidence or operate automatically without an office in attendance.

The findings reported on these automated speed enforcement (ASE) devices reflect information from literature; personal visits to foreign law enforcement agencies and manufacturers; engineering and preliminary law enforcement field tests of selected ASE devices in the United States; a quantitative rating system; and a cost-effectiveness evaluation of selected ASE devices and their deployment strategies. It is concluded that ASE devices are technically much superior to systems presently used in the United States and, although more expensive, offer potential cost-effectiveness advantages. However, there are some legal and public opinion concerns that must be dealt with, and selected ASE devices must be modified and then tested in an operational setting in which the systems are actually employed, first, to issue warnings and, eventually, citations for speeding.

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PREFACE

This final report covers the two phase activities under Contract No. DOT-HS-8-02030. Many details of the first phase of the study--the identification of technology potentially applicable to speed enforcement--were described in an Interim Report. The scope of the work reported herein deals basically with the second phase of the study--a theoretical, engineering, and preliminary law enforcement evaluation of selected automated speed enforcement approaches.

The authors would like to acknowledge the efforts of Mr. Pat Heenan and Ms. Debra Hodge of the MRI staff for their assistance in conducting the engineering field tests and to the commanders and troopers of the Maryland, Illinois, and New Jersey State Police for their cooperation in conducting the preliminary law enforcement field tests under adverse conditions.

It is difficult to adequately express our appreciation for all the information provided by almost innumerable agencies, colleagues, companies, etc., from throughout the world. An attempt was made in the Interim Report to list all who assisted at the risk of unintentionally leaving someone out. We particularly note our hosts in the police agencies and companies visited in Europe and Japan during our fact-finding tours, all of whom were most gracious and helpful to make the potential language barriers surmountable.

The guidance and support of four NHTSA staff must be commended. Drs. Richard Compton and Michael Goodman, the Contract Technical Managers, were responsible for many key contacts, information, and special arrangements. Mr. Theodore Anderson and Mr. Harold Butz accompanied the authors to Europe, and helped obtain important data there and in the United States.

Approved for:

MIDWEST RESEARCH INSTITUTE

William D. Glauz

William D. Glauz, Ph.D.
Director, Center for Safety and
Engineering Analysis

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EXECUTIVE SUMMARY

Speed limits and their enforcement have long been considered important contributors to the maintenance of safety on highways. Greater emphasis on these activities has arisen since the OPEC oil embargo of 1973. Subsequent to that event much national effort has been directed toward the conservation of petroleum products. A major result of these efforts has been a series of Congressional actions that includes the imposition of the 55 mph National Maximum Speed Limit (NMSL) and progressive compliance goals to be met by the States.

Enforcement of the NMSL, along with public education, is a fundamental means of achieving better compliance, but the law is unusually difficult to enforce. Despite the fact that numerous opinion surveys have indicated that most people are in favor of the speed limit, the majority of drivers violate it at least part of the time. Thus, law enforcement agencies have often found themselves perplexed in their efforts to bring about better compliance with limited manpower.

The purpose of the research reported here is to identify and evaluate technologies other than those already employed routinely in the United States that might be useful in aiding law enforcement agencies in their efforts to achieve better compliance with the 55 mph NMSL. The major emphasis is on automation, or automated speed enforcement (ASE) devices or technologies, the use of which could ease the demands on agencies constrained to operate within statutory personnel ceilings. The research focused on technologies and associated procedures developed to the point where they could be directly implemented or, in fact, have already been widely utilized elsewhere in the world.

The research was initiated by an exhaustive search for relevant information. In addition to routine literature searches, officials of numerous federal agencies and other American researchers were contacted. Then, foreign embassies, consulates, trade councils, and researchers were also queried about overseas speed enforcement practices and technologies. Personal visits were made to 22 European and 7 Japanese law enforcement agencies, manufacturers, and research organizations. Over 50 concepts, devices, or systems were identified, most of which are being, or have been, deployed for speed enforcement or research purposes. Several of these systems were further identified as being potentially most useful in the United States and being potentially capable of fully automatic operation.

All ASE devices have one feature in common--they have the capability of being coupled with a camera system to produce a picture of the speeding vehicle and its license plate, as well as recording certain other information such as the vehicle speed, date, time of day, location, etc. The detection portions of the ASE devices employ various methods for making speed measurements, but most common is cross-the-road Doppler radar. Many of the ASE devices are capable of being deployed in fully automatic, unmanned operation freeing police officers for other functions.

The systems identified by MRI as being potentially capable of fully automatic operation were evaluated both subjectively and objectively, using a numerical rating scheme. The results of the preliminary assessment were documented in an Interim Report which also described the technological advancements identified, a summary of the information collected in support of the utility assessment, and recommendations for further evaluation of ASE devices. The recommendations formed the basis for additional work on the contract and called for the engineering field testing and preliminary law enforcement field evaluation in the United States of several types of ASE systems. The purpose of these tests was to assemble data on first-hand experience with the systems that could be used to determine the effectiveness of ASE devices for speed control in the United States.

Six European-manufactured ASE devices were selected for preliminary shakedown and field evaluations in the United States. However, only 4 of these could be readily obtained from the manufacturers. The ASE devices acquired for testing were: Gatso Mini Radar Model MK4, Multanova Model 4FA, Traffipax Type V/R, and Truvelo Model 4.

The 19 engineering field tests conducted with the 4 selected ASE devices were sufficient to obtain necessary operational familiarity with the systems to develop training materials for police officers and to establish bounds and limitations on the capabilities of the systems. No one system was found superior in all the 19 tests conducted.

One of the primary findings of the engineering tests indicated the use of a longer camera lens (longer than the 75 mm supplied with the device cameras) would greatly enhance the readability of the United States license plates from the photographic negatives. The incremental improvement between a 75 mm lens and a 135 mm lens was greater than the incremental improvement between a 135 mm and a 200 mm lens. The use of color film (as opposed to the manufacturer-recommended black and white film) also enhances the positive identification of the state origin of the license plate and improves the readability of some license plates with poor color contrast.

Preliminary law enforcement field tests of the 4 ASE devices were conducted by units of 3 state police agencies. These tests were sufficient to assess the police training requirements; identify potential problems associated with the use of the devices; and evaluate the general acceptability of the devices by the law enforcement personnel.

Generally, the troopers had something good to say about the operation of each device. A majority of them thought the most highly automated device was the best. They also made suggestions for reasonable engineering improvements for each device that would help overcome some of the devices' operational deficiencies. A typical suggestion was that the units be more compactly designed to enhance their portability/mobility. The state police commanders/supervising officers involved with the tests generally thought the ASE concept to be excellent, and that the most efficient deployment strategy was to use the devices in a fully automatic mode of operation.

Vehicle owners could be identified in over 90% of the cases if the license plate number could be read and the state identified. However, many problems were encountered by the film reviewers trying to read the license plates of the violating vehicles, irrespective of the device. The name of the state and the expiration date on the plate were almost always too small to be read, even for vehicles in the near lane. The state of registration had to be deduced from the format of data on the plate. The use of a longer focal length lens was again a suggested solution to the readability problems. It must be emphasized that many of the limitations cited in the tests relative to license plate readability could be alleviated through license plate redesign. In most of the world, the vehicle license plates are much larger than in the United States, and have large, high contrast letters and numbers.

A number of legal issues have been raised regarding the employment of ASE devices, especially when they involve photography. Most of the concerns have been found not to present formidable legal barriers to their employment in the United States. The one exception is the vicarious liability problem, which arises with photographic systems when only the vehicle owner can be identified (through the license plate), and not the driver. A number of approaches to dealing with this problem are suggested in the study.

The public acceptance issues pertaining to the use, or potential use, of ASE devices in the U.S. are many-faceted and complex. A recent study of the public acceptability of highway safety countermeasures reported an investigation into the acceptability of ASE devices. Unfortunately, the results cannot be used to assess the public acceptance of ASE devices in the U.S. because of the incorrect interpretations conveyed to those surveyed.

An analysis of the selected ASE devices and their deployment strategies shows that the more automated systems are more cost-beneficial on a cost-per-arrest basis. The fully automatic systems equipped with a 135 mm lens would have the lowest cost per arrest of any system--between $0.73 per arrest for the Multanova and $0.84 per arrest for the Gatso. These compare to almost $4.50 per arrest for a single officer operating a stationary, American, down-the-road radar system. The cost per arrest estimates for the ASE devices plus foreign experience with their demonstrated productivity suggest the devices could be highly cost effective in increasing compliance with the 55 mph NMSL, despite their higher initial costs.

Despite such potential effectiveness, ASE technology has not been implemented in the United States. If law enforcement agencies are to include such technology and associated procedures in their overall speed limit enforcement plans, certain actions must be carried out first. Engineering modifications should be made to the ASE devices, as tested, to enhance their portability/mobility and make them less susceptible to adverse weather problems. The modified ASE devices should then be tested in an operational setting in which the systems are actually employed, first to issue warnings, and eventually to issue citations for speeding. In support of the operational field testing activity, public information strategies need to be developed that can make the affected public aware of the general concept of ASE devices and associated deployment strategies. Also, model legislation should be developed that will assist jurisdictions in implementing the required legislation to permit field testing of a citation-oriented ASE strategy. Data then need to be acquired to determine the effectiveness of ASE devices compared to that of American radar to deter speeding in the United States.

I. INTRODUCTION

A. Need for the Study

It has long been recognized that accidents occurring at higher speeds are more likely to result in fatal or serious injuries than those at lower speeds. For this and other safety reasons, states and municipalities have passed laws and placed speed limits on their roads, and instructed their police personnel to enforce these limits. The National Highway Traffic Safety Administration (NHTSA) has, for years, funded research and provided funds, through its 403 and 402 programs, to help support more effective enforcement efforts.

The OPEC oil embargo of 1973, which created a temporary fuel shortage in the U.S., resulted in a great impetus toward reducing speeds and speed limits, and increasing speed enforcement. The Emergency Highway Energy Conservation Act[1] and the Federal-Aid Highway Amendments of 1974[2] required each state to enact and enforce a maximum 55 mph speed limit (now called the 55 mph National Maximum Speed Limit or NMSL). Subsequently, the U.S. Congress required the states to establish speed monitoring programs. Compliance goals were set for the years 1979-1983, and sanctions and incentive grants were developed in the Surface Transportation Assistance Act of 1978.[3]

There is little doubt that these actions did, indeed, reduce average speeds (and speed variances) on the highways. Likewise, it is generally agreed that fuel consumption was decreased and that safety benefits were realized, although the magnitudes of these effects are constantly being debated.

Speed data collected by the states and numerous other sources revealed that, whereas average speeds dropped appreciably in 1974, they began to increase noticeably thereafter, reaching averages in the 58-62 mph range. Federal Highway Administration (FHWA) data[4] indicated that most if not all states met the 1979 compliance goal on 55 mph roads (at least 30% compliance on a vehicle miles of travel basis). However, the progressively more stringent goals of more recent years became difficult to satisfy. Approximately a dozen states, located mostly in the western half of the nation, did not meet the 1980 goal in 1979.

Increased compliance is extremely difficult, according to most law enforcement officials. While a majority of the public say they support the 55 mph NMSL, nevertheless most drivers violate it, at least some of the time. To increase compliance, a variety of public information and education campaigns have been devised in the past. These campaigns have been both national and local in scope, but their impact has largely been unmeasured or unmeasurable.

Enforcement efforts have been increased. Many states have utilized special patrol strategies, such as saturation techniques, selective enforcement, covert techniques, use of CB radios, combining enforcement with public information, etc. Officials express doubts as to further increases in effectiveness of such approaches, primarily because of manpower limitations (as well as budgetary constraints). Some also indicate difficulties in ticketing and convicting those traveling at just slightly over the speed limit - e.g., 56 or 57 mph.

Speed enforcement has long been enhanced by the application of technology. Of particular importance have been the use of radio communications, computerized data bases, aircraft surveillance, and radar. The latter, in particular, has been used by nearly every law enforcement agency to enforce speed limits. Radar units are available from numerous manufacturers in the U.S.; models can be purchased for operation in either fixed or moving modes, and in either hand-held or vehicle-mounted configurations. However, their accuracy and reliability have been questioned on several counts,[5] including their ability to reject false signals, to provide accurate readings, and to discriminate between vehicles. The National Bureau of Standards recently determined that the U.S. radar units are, in fact, accurate and reliable "when carefully installed and properly operated by skilled and knowledgeable operators."[6] They do not automatically discriminate between vehicles, however, which makes them unsuitable for use in heavy traffic or for adaptation to automatic speed enforcement.

Clearly, the problem of achieving better compliance with the NMSL, and with speed limits in general, is very difficult. Increased compliance will undoubtedly require continued development and application of new ideas. These ideas include, of course, still more experimentation with manpower deployment strategies, public information and education, and their coordination. However, education and the increased efforts by personnel, alone, may not be enough. Cost-effective approaches to improving compliance can potentially be achieved through application of modern technology. To this end, this study was devised to identify the technologies that may be applicable to speed enforcement--particularly, automated speed enforcement--and, secondly, to assess the practical feasibility of such technologies in the U.S.

B. <u>Scope of This Report</u>

The work conducted under the contract was divided into two phases. The first phase of the study--the <u>identification</u> of technology potentially applicable to speed enforcement--was described in an Interim Report.[7] The report emphasized technology and related enforcement practices not currently used in this country, but which <u>are</u> commonly employed elsewhere in the world. The report focused strongly on automated systems which may ease manpower limitations.

The term "automated" refers to the technology that relieves the police officer of one or more normally manual functions. These functions, include determining the speed of a vehicle, identifying the vehicle(s) exceeding a set speed, and documenting the violation. Thus, the definition is quite broad. It includes devices (such as radar) which measure speed, up to and including totally automatic systems that measure speeds, "identify" speeding vehicles and photograph them together with their speed, time, date, etc.--all without need for police officer presence.

The Interim Report focused on devices and techniques that could be employed to make the police officer's task of speed enforcement more efficient, leading to better compliance without excessive costs. The first phase culminated with a set of recommendations that included further evaluation of selected automated speed enforcement (ASE) devices during a second phase portion of the study.

The scope of this report deals basically with the second phase of the study--a theoretical, engineering, and preliminary law enforcement evaluation of selected ASE approaches. The report does not dwell on enforcement strategies except as they are suggested or dictated by the implementation of the selected ASE devices. Similarly, the report touches on legal and public opinion issues, but only in support of the technology applications and not as subjects unto themselves. As such, the work reported lays the groundwork for future implementation of ASE devices and deployment strategies.

C. Organization of the Report

Chapter II summarizes the seven-step methodology followed in arriving at the research findings presented in this report. This methodology included: a search for advanced technology, the development of an assessment methodology, the collection of data on speed enforcement technology, the determination of the potential utility of ASE technology, the conduct of engineering field tests, the conduct of operational/procedural field tests of selected ASE devices, and the final evaluation and comparison of the selected ASE devices.

Chapter III presents a summary of the extant technologies and devices identified in the study and the range of enforcement strategies used or usable with these technologies. Particular emphasis is given to the ASE devices tested. More detailed descriptive information on these particular devices is given in the Interim Report.[7]

Chapters IV and V briefly examine the constitutionality/legality and public acceptance issues associated with the potential use of ASE devices. Most of this examination is based on foreign practices and how these issues affect the equipment choices and enforcement strategies employed. These chapters also include a brief summary of recent U.S. studies and includes their major conclusions about legal and public acceptance issues in the U.S.

Chapter VI contains a summary of 19 engineering field tests conducted with four selected ASE devices. The significant findings of the tests are highlighted; the details of each test and the associated data analysis are presented in Appendix A.

Chapter VII presents a summary of the experience gained by three U.S. state police agencies in trials with the four selected ASE devices. It includes the enforcement personnel's objective and subjective evaluations of the four ASE devices and implementation modes. The evaluations assess the various aspects of the preliminary agency testing including: training requirements, ease of set-up and operation, capabilities of the ASE devices under a variety of operating conditions, ease with which film can be processed and appropriate information obtained, and potential problems with the devices.

Chapter VIII brings together information and data obtained during the contract for the purpose of comparing the selected ASE devices and enforcement strategies. This chapter contains two major components: comparative ratings of devices, and cost/effectiveness estimates. A summary is given of the numerical ratings of the selected ASE systems using a number of deployment strategies. The details of these ratings are presented in Appendix B. Also discussed are cost/effectiveness estimates calculated for each ASE system-strategy combination. The figures presented are estimates of projected U.S. enforcement costs per arrest, based upon the data collected during the research.

Chapter IX presents recommended improvements to selected approaches appropriate to U.S. implementation. Both devices and strategies are considered. These recommendations are based upon the data collected from the engineering and preliminary law enforcement tests.

The last two chapters present the conclusions and recommendations based upon the findings of the research. Some of the recommendations address follow-on implementation and tests of ASE devices and deployment strategies in the U.S.

II. RESEARCH METHODOLOGY

The research findings presented in this report resulted from a seven-step methodology. These seven steps are briefly described in the following sections.

A. Search for Advanced Technology

This portion of the study identified and obtained preliminary information on technological advances (devices) that might be used for the deterrence of speeding. Included in the search were devices specifically designed for speed control as well as devices and concepts that might be so used even though they had not yet been implemented in that way. No restriction was placed upon the national origin of the devices, i.e., both U.S. and foreign devices were investigated.

The search for devices was a multi-directed activity that drew upon the knowledge, expertise, etc., of many sources of information. These included:

* Various U.S. government agencies;
    - National Highway Traffic Safety Administration (NHTSA);
    - Federal Highway Administration (FHWA);
    - National Bureau of Standards (NBS);
    - U.S. Naval Surface Weapons Center (NSWC);
    - Federal Communication Commission (FCC);
    - Law Enforcement Assistance Administration (LEAA);
* Contractors working on related projects;
* Manufacturers known to MRI at the beginning of the study;
* State Highway Patrol agencies;
* Other state agencies;
* Representatives of foreign governments (Embassies and Consulates);
* Foreign trade councils;
* Overseas research colleagues of MRI;
* Organization for Economic Cooperation and Development (OECD);
* Trade journals; and

* Computerized literature search.

Many of the initial contacts made with the above groups generated leads to secondary overseas sources (e.g., other manufacturers, researchers, traffic agencies, testing/certification laboratories, and law enforcement agencies), which were also contacted. Valuable information on device manufacturers and potential concepts were obtained from past and ongoing contracts funded by both NHTSA and FHWA.[8-13] Of particular importance to the search was an annotated inventory of U.S. and some foreign speed measuring devices prepared by NBS.[14]

A computerized literature search was run using Battelle's TRIS (Transportation Research Information System). This multi-component data base consists of abstracts of about 50,000 ongoing or recently completed transportation research projects. The literature search sought information pertaining to the following major subject areas:

* Speed detection devices;

* Use of speed detection devices for law enforcement; and

* Legal aspects associated with speed detection devices, particularly those employing photographic recording of offending vehicles.

The few pertinent documents found through the computerized literature search were obtained from various technical libraries, and thoroughly reviewed.

B. Develop Assessment Methodology

In order to estimate the potential utility of a technological advancement and to evaluate the practical feasibility of selected technology for use in the U.S. it was necessary to formulate a framework for the assessment process. A rating method was devised to make the assessments. The framework was also used to guide the collection of detailed information about possible devices and technologies.

The rating methodology is presented in Appendix B, together with ratings for a number of deployment strategies applied to selected devices. It is important to realize that technological advances useable in law enforcement for speed control can only be evaluated in conjunction with its means of implementation. The technology by itself is relatively useless; it is the application of the technology in law enforcement operations that is of interest. The same device might be quite effective when deployed in one mode of operation, and fairly worthless in another.

The assessment methodology clearly identifies three major areas of data needs regarding technological advancements:

* Technical effectiveness;

* Community acceptability; and

* Cost implications.

The first area deals with the operational characteristics of the technology in consideration of its deployment strategies, its accuracy, its ability to ignore/reject false information, environmental limitations, etc. The second area concerns the acceptability of the applied technology by the legal community, courts (as they interpret and adjudicate), the police, and the public at large (including special interest groups). The cost implications cover purchase, operation, training, maintenance, etc.

C. Collect Data on Speed Enforcement Technology

A large number of devices and/or concepts that could be, or are being used, to enforce speed limits and to deter speeding were uncovered in the search for technological advancements. As soon as a device was identified, its manufacturer was contacted, generally by letter, and asked to provide information on the product in the form of brochures, descriptions, and technical data. Also requested were the names and addresses of agencies or law enforcement jurisdictions that had used the systems.

A particularly promising technology, known as automated speed enforcement (ASE), was identified in the search. All ASE devices have one feature in common--they have the capability of being coupled with a camera system to obtain photographic evidence of speeding violations. The detection portion of the devices employ various methods for making speed measurements, but the most common is Doppler radar.

A majority of the ASE devices identified are manufactured in Europe or Japan. Eleven European and Japanese manufacturers had ASE devices on the market. Furthermore, there were a number of different models of these devices available, each representing a different utilization. The U.S. has little experience with this type of equipment. Therefore, an extensive European field trip was made to visit 22 manufacturers, law enforcement agencies, and research agencies regarding some of the equipment. A visit to 7 Japanese manufacturers and police agencies was also undertaken.

Major insights were provided during these visits, especially, by law enforcement agencies using some of these technologies. Information sought from each agency included:

* General information about the jurisdiction;
* Devices used;
* Photographic evidence;
* Personnel requirements;
* System effectiveness;
* Legal considerations;
* Attitudes;

* Maintenance needs;
* Annual costs; and
* Field observation notes.

D. Determine Potential Utility of ASE Technology

A preliminary evaluation was performed of the technology and its application to automated speed enforcement. The evaluation was partly subjective, based on review of various documents, discussions with manufacturers and users, and first-hand observations. It was also partly objective, utilizing the rating system referred to earlier and numerical weights placed on various facets of the technology, capabilities, costs, and probable acceptance in the U.S. As a consequence of the evaluation it was determined that ASE devices were the most promising for application to the enforcement of speed limits in the U.S. The results of the preliminary assessment were documented in an Interim Report[7] which also described the technological advancements identified, a summary of the information collected in support of the utility assessment, and recommendations for further evaluation of ASE devices. The recommendations formed the basis for additional work on the contract and, specifically, called for the engineering field testing and preliminary law enforcement field evaluation in the U.S. of several types of ASE systems. The purposes of these tests would be to assemble data on first-hand experience with the systems that could be used to finally determine the effectiveness of ASE devices for speed control in the U.S.

E. Conduct Engineering Field Tests

Six European-manufactured ASE devices were selected for preliminary shakedown and field evaluations in the U.S. However, only four of the six devices could be obtained from the manufacturers in time for testing. The ASE devices acquired for testing were:

1. Gatso Mini Radar Model MK4: This is a portable device which incorporates a tripod-mounted radar made by James Scott, Ltd., of Scotland; a West German Robot data camera; and a Dutch Gatsonides data and control system.

2. Multanova Model 4FA: This ia a Swiss device designed for installation in a roadside cabinet for fully automatic, unattended operation.

3. Traffipax Type V/R: This West German device uses a French Mesta radar with a Robot camera and is designed for semi-permanent mounting in a police vehicle.

4. Truvelo Model 4: This is a portable, non-radar device from South Africa/West Germany/England that uses piezoelectric roadway sensors and incorporates a Robot camera and special data box for automatic data recording.

Details of these devices are given in Section III.

Some of the ASE devices required minor adaptations prior to conducting the engineering field tests. These involved: assembling cables; procuring batteries and cases; designing and constructing roadside cabinets for the Multanova; and installing the Traffipax in a government-furnished vehicle.

The engineering field tests were conducted by MRI in the Kansas City area. The purposes of these tests were two-fold--to obtain operational familiarity with the systems to enable us to effectively train police officers; and to establish certain bounds and limitations on the capabilities of the systems. A total of 19 separate engineering field tests was conducted with the devices. The types of information obtained from these tests included:

* Photographic capabilities by time of day (morning, day, dusk, night);
* Problems occasioned by direction of sun;
* Readability of U.S. license plates;
* Relative advantages/disadvantages of color and black/white film;
* Accuracy of speed measurements;
* Operational range;
* Ability to function in rain/snow;
* Effects of traffic density and vehicle type on speed detection;
* Methods by which motorists could fool or evade the system;
* Effects of jammers and detectability by radar detectors;
* Radar tests;
    - Cosine angle effect
    - External interference from power lines and CB radios; and
* Operational and procedural concerns of importance to law enforcement personnel.

A summary of the engineering field tests and results are presented in Section VI while the details are given in Appendix A.

F. Conduct Operational/Procedural Tests

Preliminary law enforcement field tests of the four devices were conducted by units of three state police agencies. The objectives of these tests were to:

- Assess the police training requirements;
- Identify potential problem(s) associated with the use of the devices; and
- Evaluate the general acceptability of the devices by law enforcement personnel.

Training manuals and materials were developed for each device. The documents were developed from the manufacturer-provided manuals and the results of our engineering field tests, and included such items as theory of operation, system components, operating instructions, operation without the camera, disassembly and storage, film processing and analysis, trouble shooting, routine maintenance, and special hints and precautions. The training given the troopers concentrated on field operations rather than classroom work and theory.

Operational/procedural test plans were developed for each agency that specified test site selection procedures, detailed time schedules, tests to be conducted, test procedures, data needs, and agency reporting requirements.

Each agency had the opportunity to use three or four of the ASE devices for from 4 to 6 weeks. In addition, each device was tested using a variety of deployment configurations depending upon the equipment, enforcement capabilities, and geographical region. The type of variables considered included: type of roadway, pavement surface conditions, environmental conditions, and detection with and without photographs taken.

All the deployment strategies using the photographic capability were implemented to the point of processing and viewing the film, identification of license numbers, and determining procedures necessary for retrieval of vehicle owner identification. No contact was made with the violators detected and/or photographed.

Evaluation reports documenting the state police agencies' experiences with the ASE devices and the results of the film analyses were submitted to MRI at the end of the preliminary law enforcement field tests. Debriefings were conducted with two of the police agencies to obtain their experiences and opinions on the ASE devices tested. Similar data from the third agency was received in a report. A summary of the state police agencies' experience is given in Section VII.

G. Evaluate and Compare Selected ASE Devices

The evaluation of the preliminary application of selected ASE devices to speed enforcement in the U.S., based on field test information, is the major emphasis of this report. The evaluation concentrates on the selected equipment and the enforcement experience with it. Part of the evaluation of each device includes an assessment of the training requirements, the ease of set-up and operation, the capabilities of the device under a variety of conditions, the ease with which the photographic film can be processed and appropriate information obtained, and the problems and potential problems associated with its use. The other part of the evaluation utilizes the rating system referred to earlier. Finally, the selected ASE devices are compared using the results of the rating system.

III. SUMMARY OF EXTANT TECHNOLOGY ADVANCES AND ENFORCEMENT STRATEGIES

A. ASE Devices

The search for technological advancements that have been, or potentially could be, applied to speed enforcement was indeed fruitful. Over 50 concepts were identified, most of which have actually resulted in devices that are either being used operationally for speed enforcement somewhere in the world or were used for research purposes. These concepts/devices are described in detail in the Interim Report.[7] The particular systems selected for field trials are reviewed here.

Many systems were found to be of special interest because of their potential of substantially reducing police manpower efforts in speed enforcement. These systems have, in common, some means of automatically discriminating among the traffic those particular vehicles exceeding a preset limit, and then providing identifying evidence. Typically, this evidence is in the form of a photograph, although video, etc., evidence is also a possibility. These systems thus can, in principle if not in actual practice, be operated totally automatically without a police officer in attendance.

Many of the systems examined use of the Doppler radar. However, the physical principle of Doppler radar is applied in a manner quite different than is used in the United States. The way in which these systems are implemented, sometimes referred to as cross-the-road radar, is presented next. This is followed by a description of the radar-based systems and the other systems of particular interest for field trials. Finally, there is a short discussion of the photographic output, with examples.

1. Cross-the-road radar vs. down-the-road radar: Radar devices used in the United States emit a microwave beam that is directed "down-the-road," usually head-on into oncoming traffic. The reflected Doppler signal is then converted into a speed measurement. While the radar principle is highly accurate (as are the U.S. devices), the down-the-road concept suffers from operational deficiencies. Although the U.S. radars often can determine vehicle speeds at long range (1/4 to 1 mile), they are not able to easily discriminate between vehicles; this task is left to the officer. If two or more vehicles are visible to the beam, judgment must be used as to which vehicle is producing a "reading." With some units it is the vehicle presenting the largest target, which is a function of size, nearness to the transmitter, and flatness of the frontal area. Other units produce the speed of the fastest vehicle in view. Thus, American radar requires officer judgment, cannot be used in heavy traffic, and does not permit easy separation of speeding vehicles in a queue (only the first or largest vehicle would normally be detected). In addition, although any apparatus can be misused by insufficiently trained and experienced officers, down-the-road radar as currently used in the United States (relying greatly on human judgment to discriminate among vehicles and confirm a speeding violation) is particularly subject to inaccurate or erroneous results. This is especially true of the "moving" radar.[6]

The cross-the-road radar systems use a very narrow, low-power beam directed at an angle (typically, 20 degrees or so) to the direction of traffic, as shown in Figure 1. Then, signal-processing logic corrects the reflected Doppler frequency for the cosine effect and ascertains whether a stable speed is being observed. Upon passing the logic tests designed by the particular manufacturer, a speed reading is displayed. The vehicle to which it applies is readily apparent to an observer viewing along the beam. If more than one vehicle is in the beam at once, normally no reading will be displayed. Because of this ability to "localize" the speeding vehicle, most such devices also permit the attachment of a camera system which can be automatically triggered to photograph the vehicle crossing the beam. The cross-the-road systems are most frequently directed towards receding traffic, as illustrated by Figure 1, but they could also be set up to look at oncoming vehicles, again by aligning the beam at a prescribed angle across the roadway.

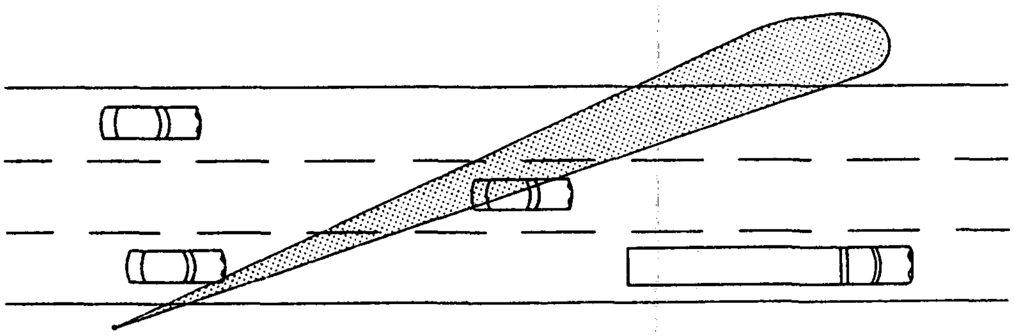


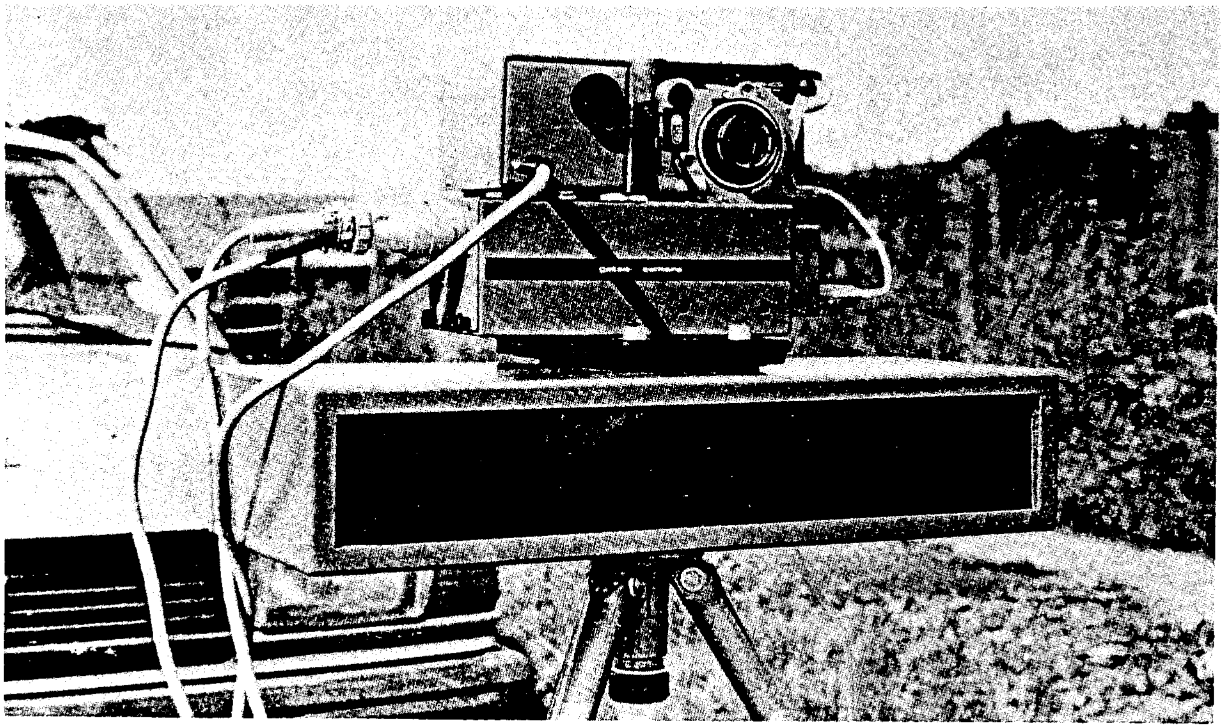
FIGURE 1. ILLUSTRATION OF THE CROSS-THE-ROAD CONCEPT.

Among the advantages claimed for cross-the-road radar systems are their ability to make positive identification of speeding vehicles; to detect nearly all speeders, even in dense traffic (time-headway separations of only 1/2 to 1 sec are required); to be relatively free from effects of electrical and other interferences; to require relatively low power microwave emissions; and to be effective even against vehicles with radar detectors (the vehicle is in the beam and its speed is registered before a detector could warn the driver and he/she could react).

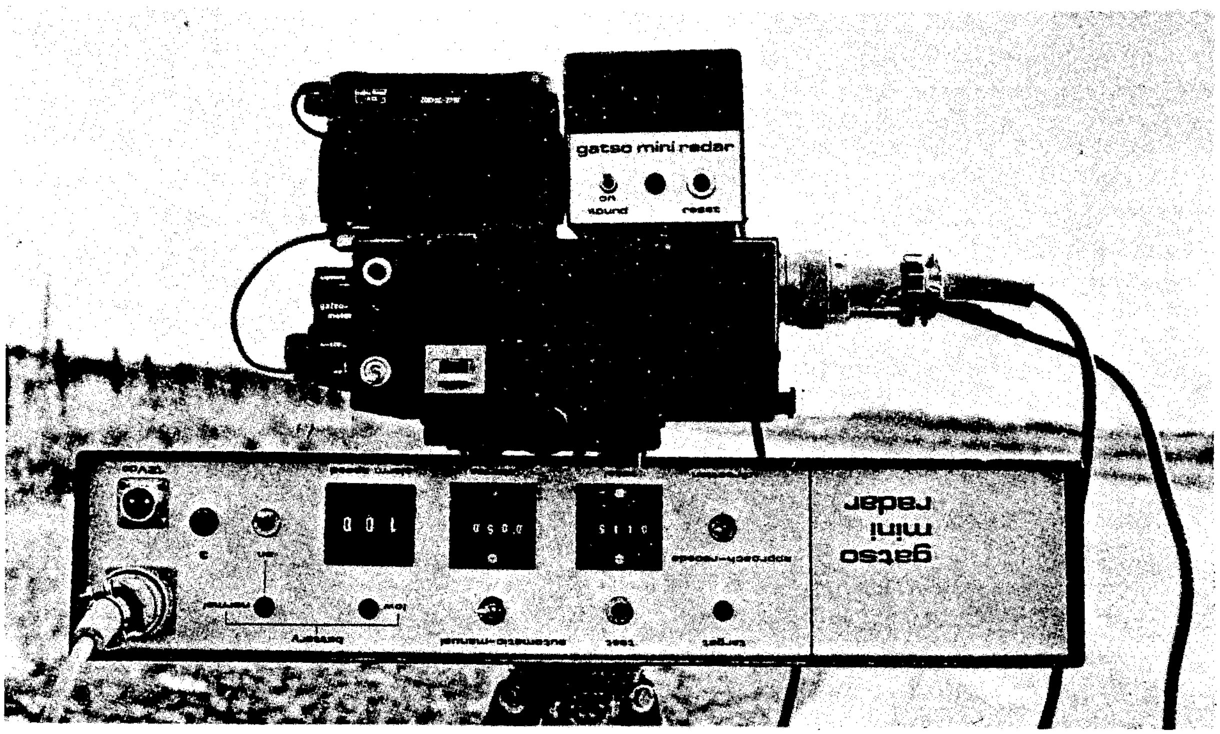
2. <u>Description of speed enforcement systems selected for field trials</u>

a. <u>James Scott, Ltd., and Gatsometer, B. V.</u>: These two firms, in Scotland and Holland, respectively, jointly produce a number of speed enforcement systems. The radar and control logics were developed by the Scotish firm. The larger rectangular unit shown in Figure 2a is the front view of the radar antenna/receiver. The model shown produces a microwave signal from the unit whose face measures approximately 4 x 21 in. The back side of the same unit contains switches, counters, etc., for the user. (Note, it is upside down in the photograph because it is aligned at an angle from the left side of the roadway. It is simply turned over to form the proper angle from the right side.)

The camera in the upper right side of Figure 2a is a German-made Robot. It and the radar are assembled as a system by the Holland firm.



a. Front View.



b. Rear View.

FIGURE 2. GATSO MINI RADAR MK4.

They also add the data box (the second longest unit in Figure 2a, which enables display of various data items on the photograph, and a remote speed display unit (next to the camera) which can be hand held, placed in the vehicle, etc.

The system shown is the Gatso Mini Radar MK4, the most advanced of several optional systems offered by these firms. It incorporates the most sophisticated signal processing logic of any of the Gatso systems, and can separate oncoming and departing vehicles. It and several other systems produced by the firms are widely used in the United Kingdom, continental Europe, and elsewhere (at least 18 countries, in total). Although the radar antenna/receiver is upside down in Figure 2b, it operates either side up, for ease in aiming it to the right or left across a roadway.

b. Zellweger Uster, Ltd.: This worldwide firm, with headquarters outside of Zurich, Switzerland, is perhaps the most well known manufacturer of cross-the-road radar systems. They have been used by law enforcement agencies in over 30 countries, and some of its systems have been in operation for over 10 years.

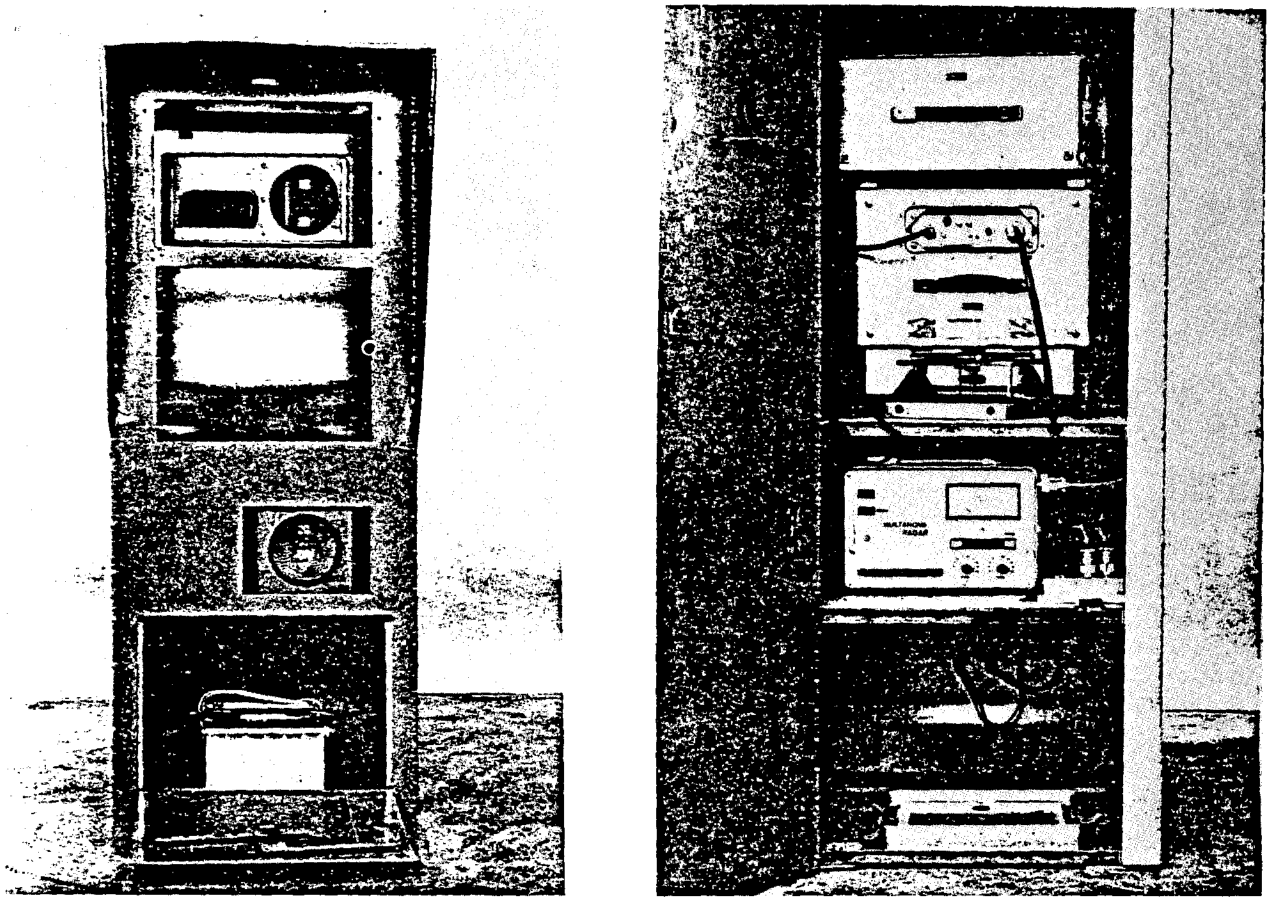
Shown in Figure 3 is one of its current models, the Multanova Radar MU VR 4FA. This particular system is designed for installation in a permanent roadside cabinet. The front view in Figure 3a shows, from the top down, the camera, the radar transmitter/receiver, the flash (for night photography), and the opened battery compartment. The rear view shows the same components (other than the battery compartment), plus the control unit, alignment device, and interconnecting cables. This configuration, using a large film magazine, is intended to operate unattended, fully automatically, for extended periods.

c. Traffipax-Vertrieb: This West German firm is a subsidiary of Robot Foto und Electronic, a company best known for its photographic systems. The subsidiary markets a "stand-alone" camera system for law enforcement use. They also market a complete speed detection system using a French-produced radar, illustrated in Figure 4.

The radar transmitter/receiver is the rectangular box on the tripod in Figure 4a. Manufactured by the Societe de Fabrication d'Instruments de Mesure (S.F.I.M.), it is known as the MESTA 204 DD radar. The radar and its control unit, which employ the cross-the-road concept, can be used alone for speed enforcement, or can be coupled with a camera and related components to form a total system, such as the Traffipax Model V/R.

Figure 4b shows the radar control unit in the glove compartment of a patrol vehicle. Connected to it on the left, by cable, is the photographic control unit and data box. The camera and its other accessories are above the latter unit. The camera is also visible behind the windshield in Figure 4a. The manufacturer states that Traffipax systems are in use in over 40 countries.

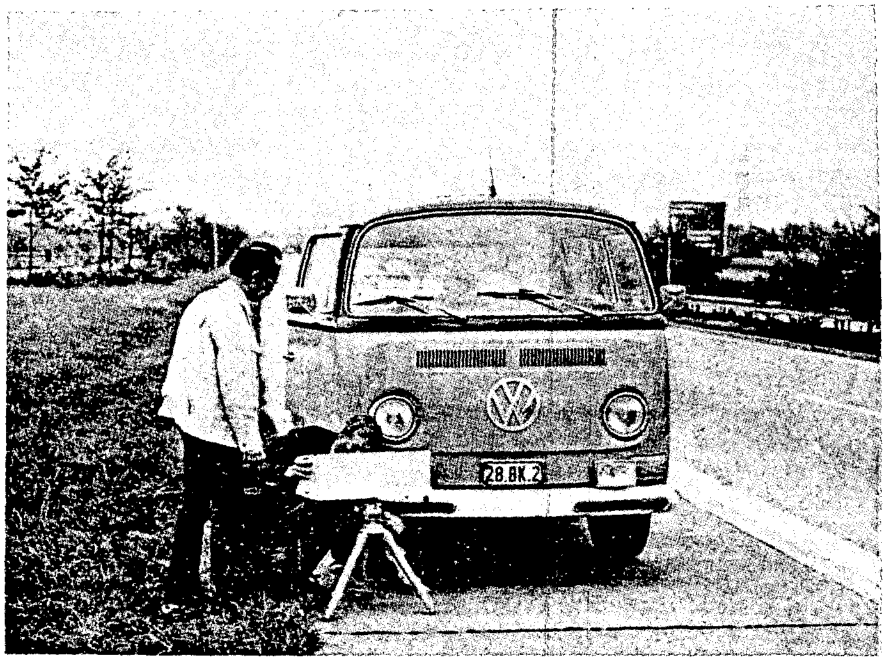
d. Truvelo: Figure 5 shows an entirely different type of system, the Truvelo Model 4. The manufacturing firm has its headquarters in South Africa, with a plant also in West Germany and a sales office in the United Kingdom.



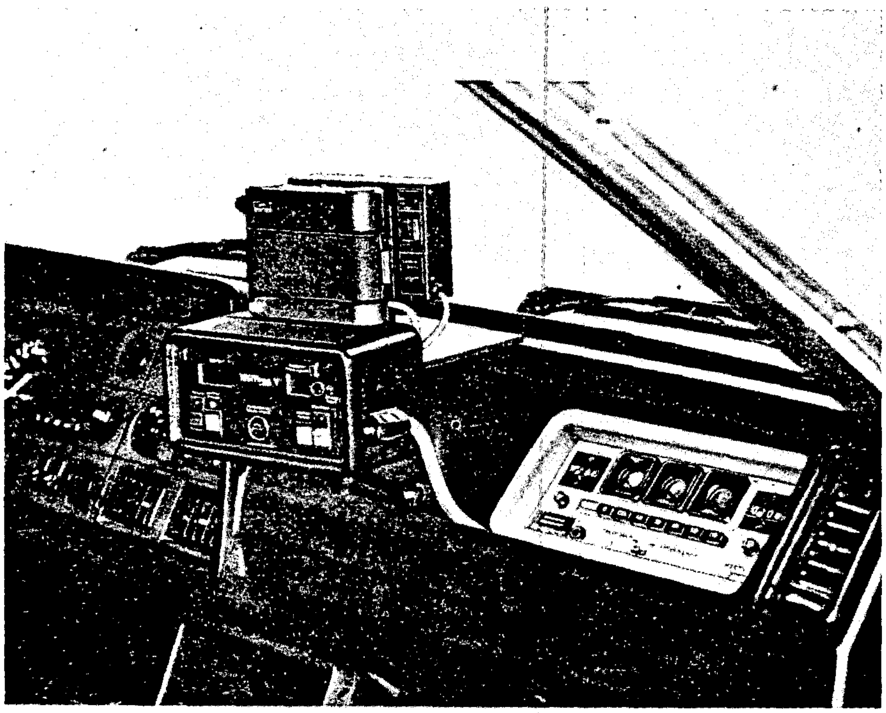
a. Front View

b. Rear View (Door Opened)

FIGURE 3. MULTANOVA INSTALLATION.



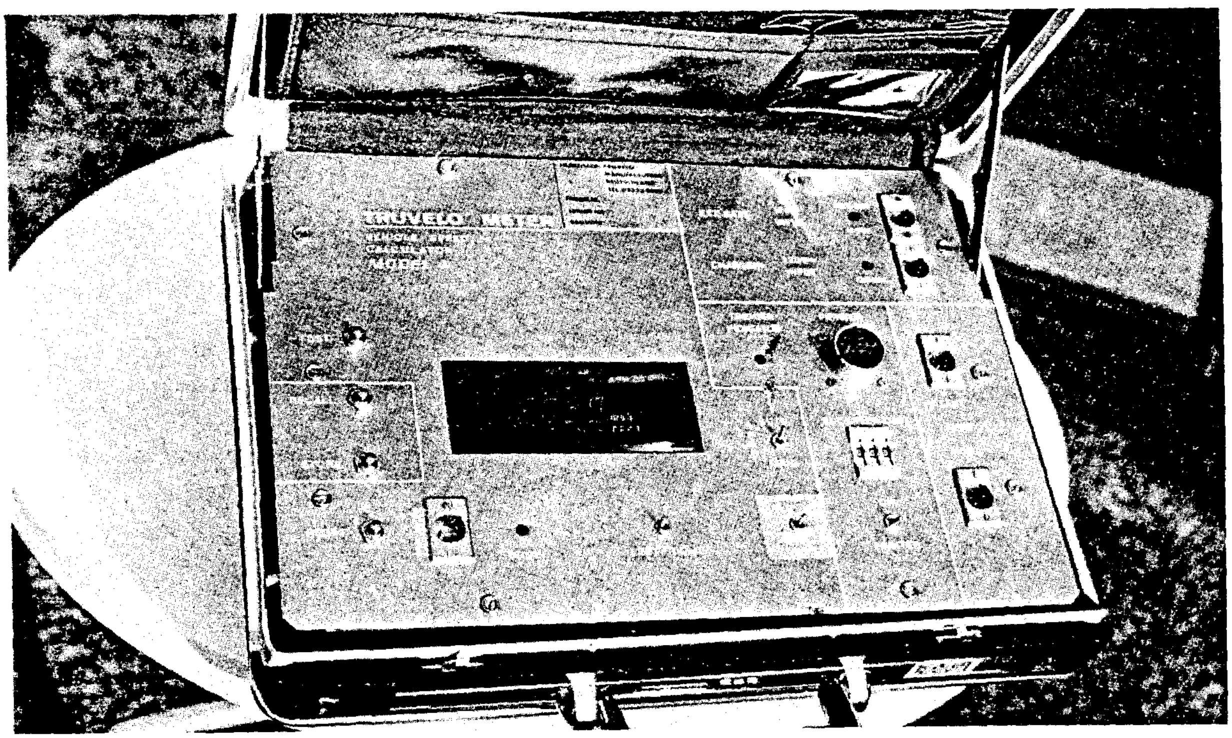
a. S.F.I.M. radar.



b. Control unit, data box, and camera.

FIGURE 4. TRAFFIPAX MODEL V/R.

a. Cables.



b. Control and display unit.

FIGURE 5. TRUVELO MODEL 4.

Sensing is accomplished via two thin, patented coaxial cables, stretched across the lane(s) of interest at a fixed distance (1.5 meters) apart, as shown in Figure 5a. Each cable employs the piezoelectric principle: when pressure is applied (for example, when a vehicle crosses it), a small voltage difference is created. This voltage difference can be sensed by a control unit wired to the cable and located some distance away. The control unit then determines the vehicle speed by measuring the time required for the vehicle to travel between the two cables.

The control and display unit, together with the batteries used to power the system, are mounted in a briefcase (Figure 5b). A vehicle speed in excess of a preset value can be shown on the display, or stored in a memory. The unit can also trigger a camera and flash unit (requiring an additional power source) as well as transmit data to a remote location. The Truvelo equipment is widely used in England, South Africa, and elsewhere.

3. Photographic evidence of speeding: Figure 6 illustrates the type of photographic evidence obtained in the most common situation. The radar beam and the camera are aimed at a downstream angle across the road. Vehicles cross the beam after they have passed the radar installation. Vehicles traveling faster than a preset limit are then photographed from the rear. Note the two examples in Figure 6; the violating vehicle in the upper photograph is in the near lane; in the other it is in the far lane. In both cases, the oncoming vehicles are ignored. Note also the data display, showing the speed and time of day for each vehicle. This particular system also includes a written description of the highway location and date.

The photographic systems may also be used at night, with a flash used to illuminate the vehicle's license plate. Examples are shown in Figure 7. Note that the light vehicles reflect back more of the flash than the dark vehicles. However, even for the black, streamlined vehicle in the upper right portion of Figure 7, the license number is clearly visible.

Photographs may also be taken from the front with some systems, when the radar beam is aimed upstream. Frontal photographs are displayed in Figure 8, for a variety of situations. The Porsche in the upper left is a highway patrol car of the Holland National Police, illustrating the high-speed capabilities of the photographic systems (183 km/h = 114 mph). In the lower left view, it can be determined that the vehicle in the second lane is the one traveling at 147 km/h (91 mph), not the vehicle in the near lane; the system logic is able to sort out vehicle speeds even though the vehicles are quite close together. An extreme example is in the lower right view; the sports car (not the truck) is the one with the 131 km/h (81 mph) speed.

The manufacturers have various approaches to assist in the determination of which of several vehicles in a photograph is the "target" vehicle. The most advanced is the patented system of Zellweger Uster, illustrated in Figure 9. The overlay grid, when placed properly according to the manufacturer's instructions, clearly identifies the light-colored vehicle on the right as the target because part of it is "over" the shaded portion of the roadway.

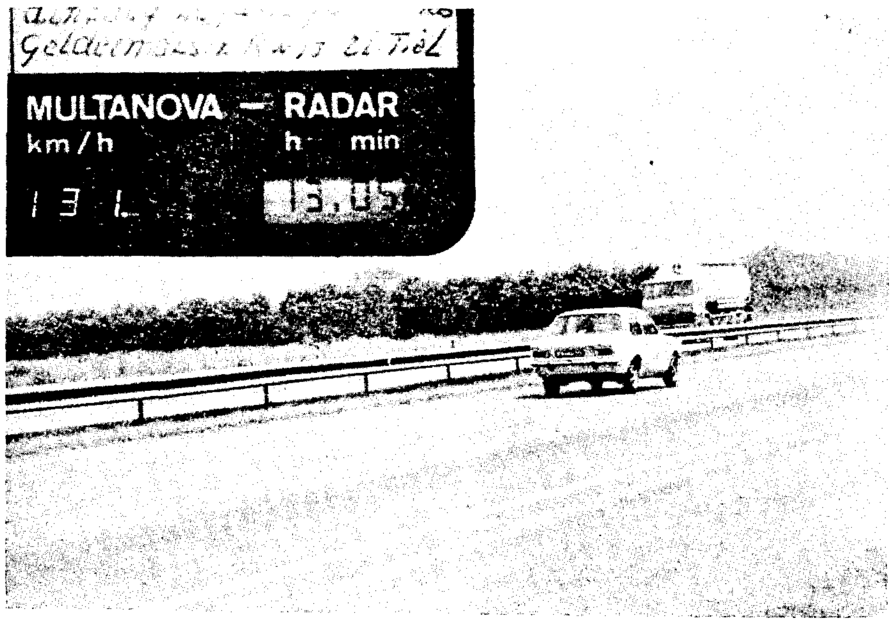


FIGURE 6. REAR PHOTOGRAPHS OF SPEEDING VEHICLES.

Photos courtesy of Holland National Police, Driebergen, Netherlands.

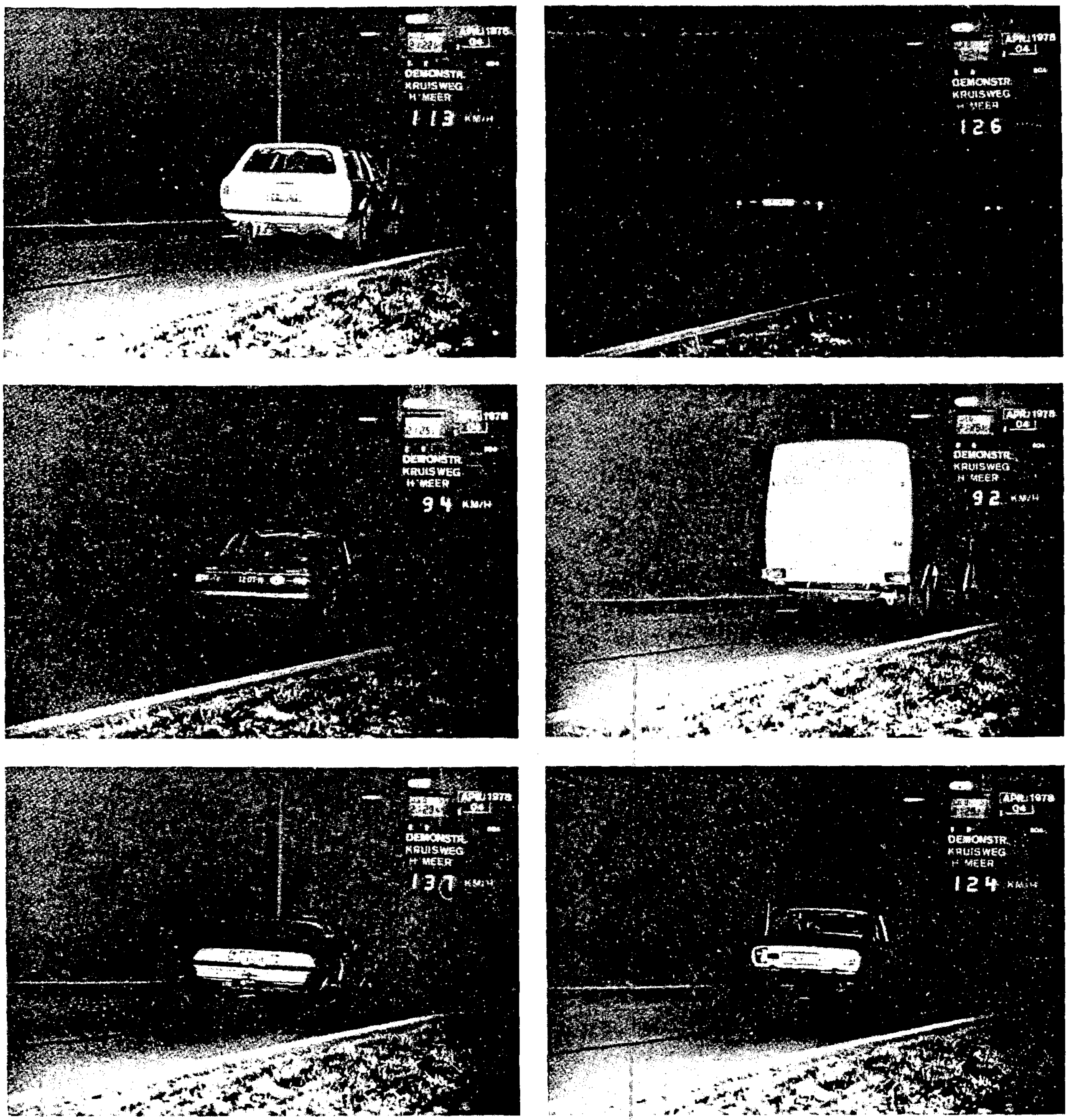


FIGURE 7. NIGHT PHOTOGRAPHS USING WHITE FLASH.

Photos courtesy of Gatsometer, B.V., Overveen, Holland.

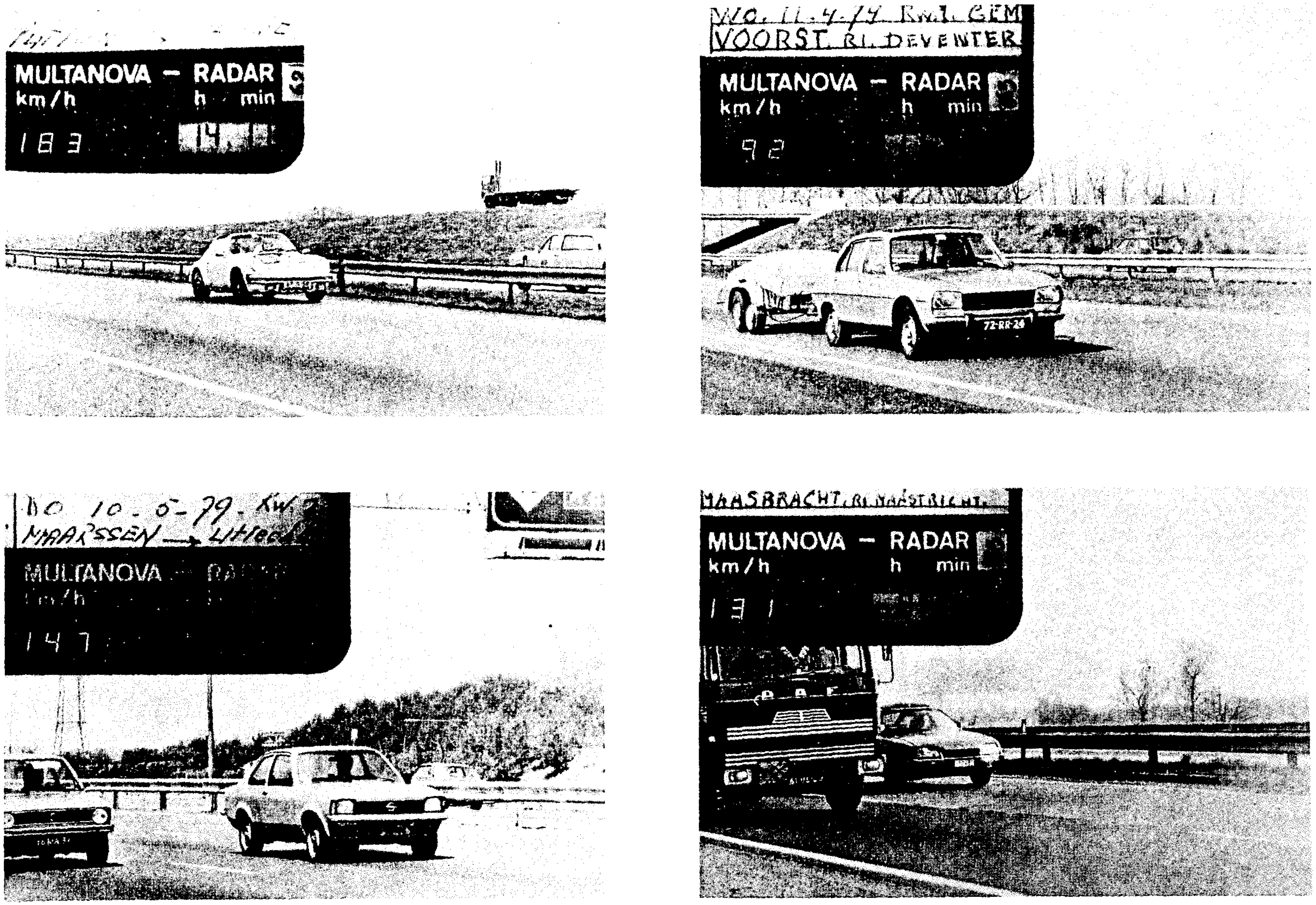


FIGURE 8. USE OF FRONTAL PHOTOGRAPHS.

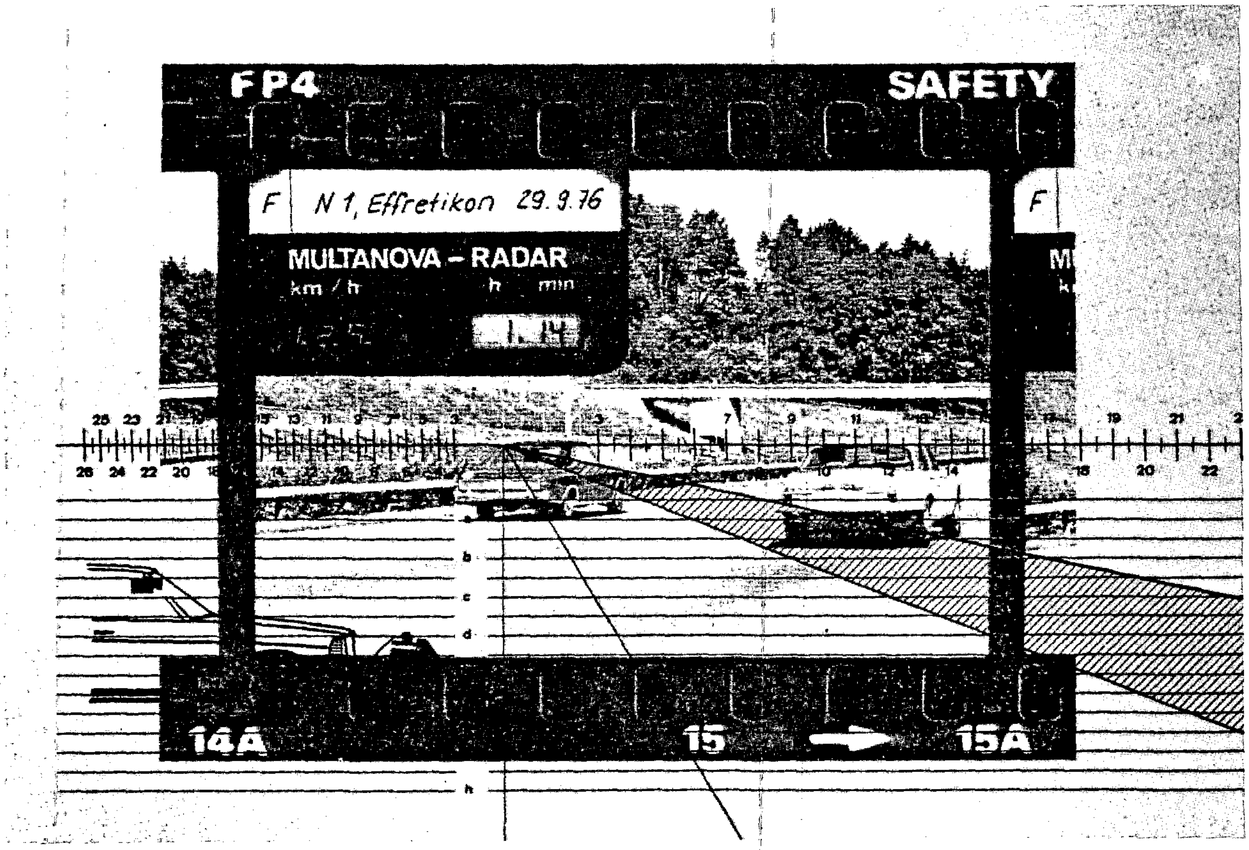


FIGURE 9. USE OF PATENTED TEMPLATE.

B. Enforcement Strategies

The approaches used in speed enforcement using automatic technology are different from those typically used in the U.S. In the U.S., most speed enforcement is accomplished by one of several techniques, such as:

* Observing traffic from a fixed location (either manually or with down-the-road radar) and then pursuing and stopping suspected violators;

* Observing approaching traffic from a fixed location, using down-the-road radar, and then stepping out and directing suspected violators to stop; and

* Observing traffic from a moving vehicle (either by pacing or with "moving radar"), and then pursuing and stopping suspected violators.

Of course, many variations of the above can be cited, including using teams, aircraft surveillance, etc. In general, however, most U.S. enforcement involves pursuit and personal contact.

With the automatic systems a variety of approaches are also used, depending on the specific equipment used, the amount of automation employed, and the specific laws and policies that must be adhered to. These approaches also must be designed to handle higher volumes of speeders, because the technologies tend to detect nearly all violations of a predetermined speed threshhold, and not just the more flagrant or isolated cases.

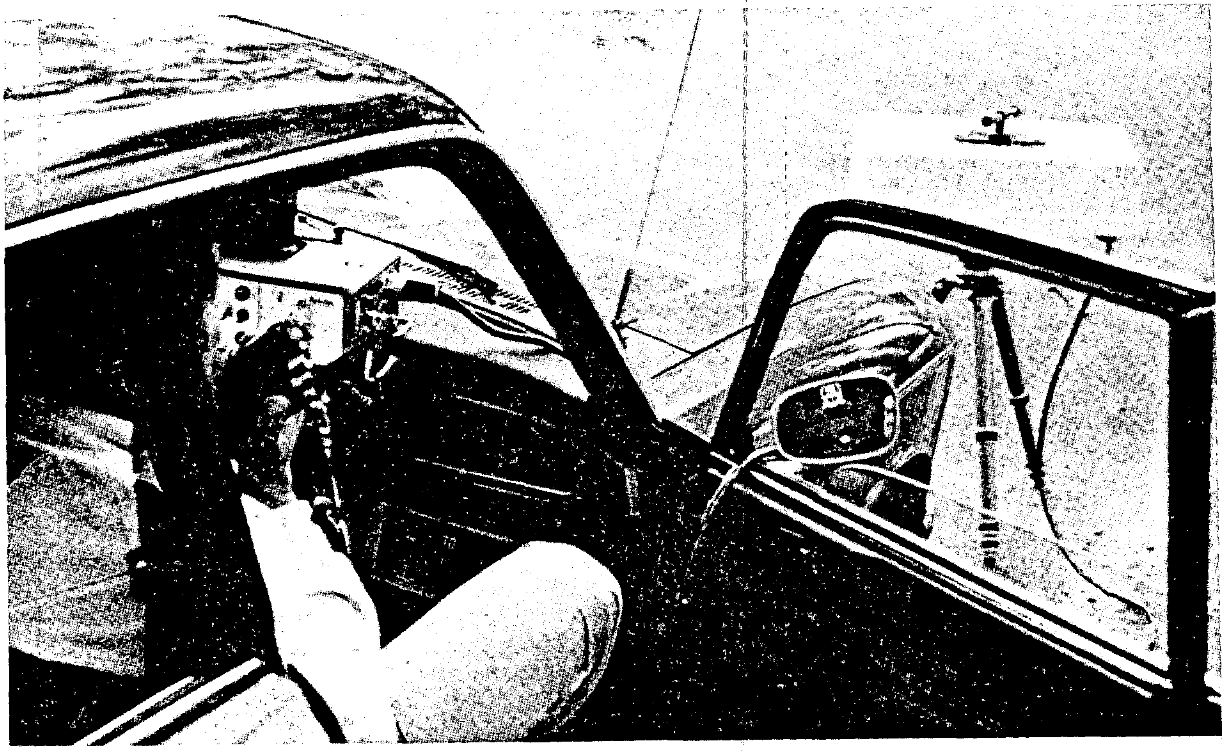
This section presents a range of strategies used by various law enforcement agencies in Europe and Japan. They are presented in order of increasing use of automation, starting with totally manned operations not too disimilar from U.S. practice, to the use of fully automatic, unattended equipment.

1. Pacing, with photographic evidence: Not all speed enforcement in Europe involves the use of highly advanced technology. In fact, pacing with an unmarked patrol car is a common strategy there, just as it is in the U.S. However, many law enforcement agencies in Europe commonly add a camera to obtain evidence of traffic violations.

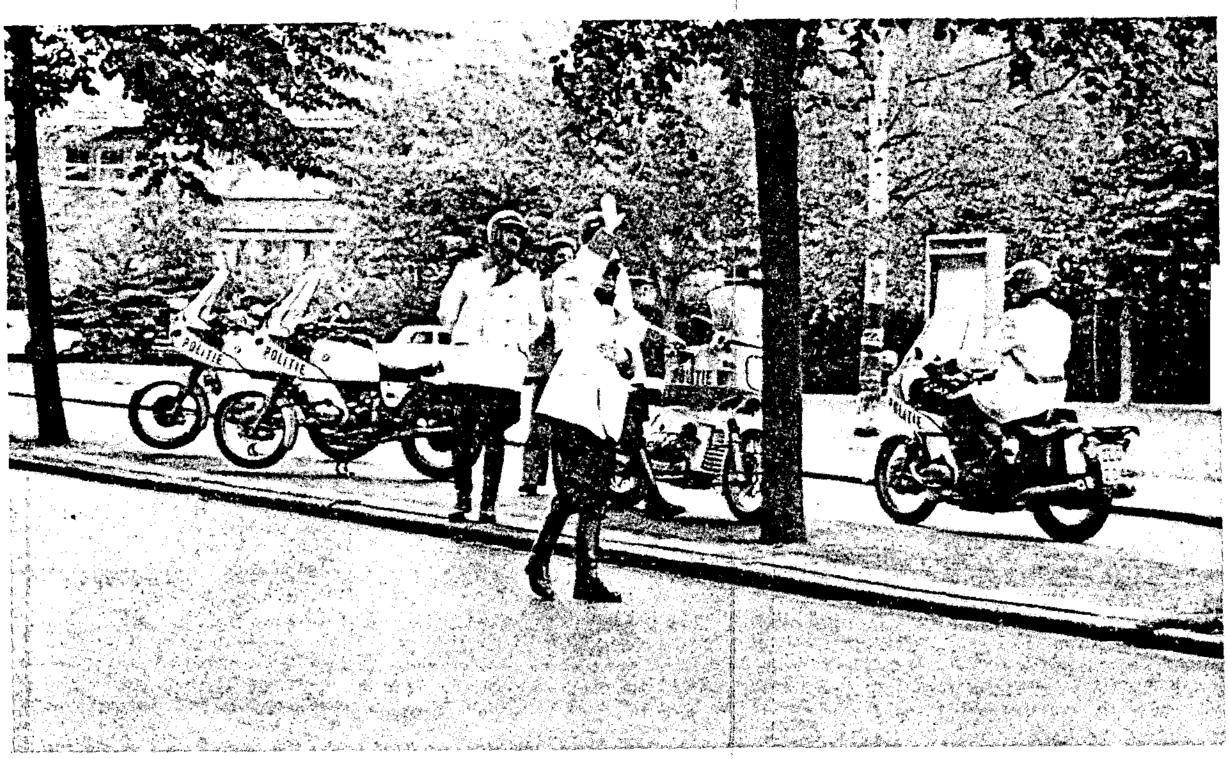
As an example of this approach, the 1,100-man traffic unit of the Holland National Police (Algemene Verkeersdienst Rijkspolitie) enforces traffic laws on the Holland highways and roads other than within the larger cities. One common method is for a 2-man team to travel with traffic. When a speeding violation is observed, the officer driving the patrol car follows the violator and the second officer triggers the camera. The system is designed to take two or more 35 mm photos at 3-sec intervals, for as long as the button is depressed. Each photograph shows the rear of the suspect vehicle as well as the speed of the patrol car, the time and date, etc. The sequential photographs document that the suspect vehicle is traveling at the speed of (or faster than) the patrol car. After obtaining the evidence, the suspect vehicle is pulled over.

Photographic evidence obtained in this way is also found useful for many other traffic offenses, such as careless driving, driving left of center, following too close, and passing on the right (which is taken much more seriously throughout Europe than in the U.S.). Of course, the photographic evidence is needed only if the case is contested. However, the mere existence of such evidence is believed to result in guilty pleas in nearly all cases.

2. Use of stop teams: A very common European strategy is to employ one of the detection systems described earlier in conjunction with a stop team stationed further down the road. Such an operation is illustrated in Figure 10, as employed by the Utrecht (Holland) City Police. An unmarked car with plain-clothed officers is parked along the curb of a boulevard, in Figure 10a, with a MESTA cross-the-road radar set on the tripod in front of the car. When a violation is noted, the speed, license number, and vehicle description are radioed ahead (about 1/2 mile in this case) to the stop team shown in Figure 10b. There, after stopping the suspected vehicle, the officer has two choices. For minor violations, and if the driver admits guilt, the fine can be collected on the spot and the driver given a receipt. For major violations, or if the driver chooses to contest the charge (or if he cannot pay the fine on the spot), formal court proceedings will be used. It is not uncommon that a number of violators will be undergoing processing by the stop team simultaneously.



a. Detection.



b. Enforcement.

FIGURE 10. USE OF A REMOTE STOP TEAM IN UTRECHT.

Another type of installation used in this manner is illustrated in Figure 11. The Rotterdam (Netherlands) City Police have installed a Gatso Mini Radar in the rear of an unmarked, blue van (which, they report, is becoming fairly well known by the populace. The back panel, which is opaque to visible light and thus hides the radar from sight, is transparent to the microwave frequency of the radar. As set along the highway in Figure 11a, the radar monitors oncoming traffic (see Figure 11b.) If a speeding violation occurs, the observing officer in the van can usually tell which vehicle is at fault by viewing along the radar beam path, which is painted on the radar unit. He then radios ahead to the stop team.

The use of stop teams, in general, is used more on lower speed roads or when traffic volumes are not too high. Most agencies tend to use more fully automatic systems in high volumes or on high speed roads, to avoid the potential safety problems associated with stopping vehicles under such conditions.

3. Manned, photographic systems: Figure 12 shows two fully automatic radar systems which are used in a manned mode. Both happen to be in use by the Belgian National Police Force (Gendarmarie). The force includes 17,000 gendarmes, of whom 900 specialize in traffic and 90 use these radar systems.

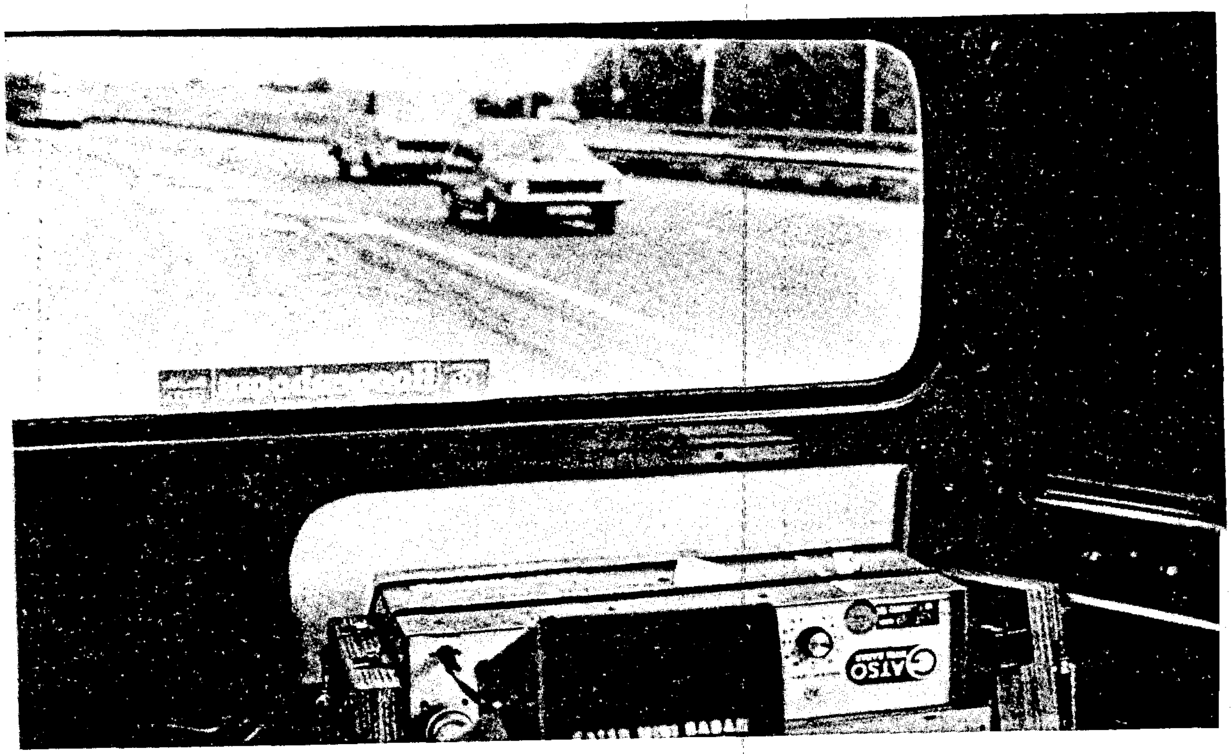
The upper photo shows a fairly old system, a Multanova Model 3F, still operable after 10 years of hard use and tens of thousands of photographs. It is mounted in a specially modified van, with a front that swings open to deploy the radar and camera units (the camera and flash are above the white-faced radar antenna). The van (and all other traffic patrol cars in Belgium) are plainly marked by a wide red stripe down the middle of the vehicle, from front to rear, by policy.

The lower photo shows the more modern Multanova Model 5F, which is replacing the model 3F. After parking the patrol car alongside the roadway, the radar antenna and flash units are set into place using special bumper mounts, and plugged into the control and camera units within the vehicle.

Both systems operate in a similar fashion. Once the equipment is set up and its calibration is checked, it operates automatically. Each vehicle exceeding a predetermined speed is photographed. Later, the roll of film is removed from the camera and processed. The license numbers are then read from the film, and inquiry into the vehicle registration files discloses the name and address of the owner. The owner is notified, and appropriate legal procedures are then followed.

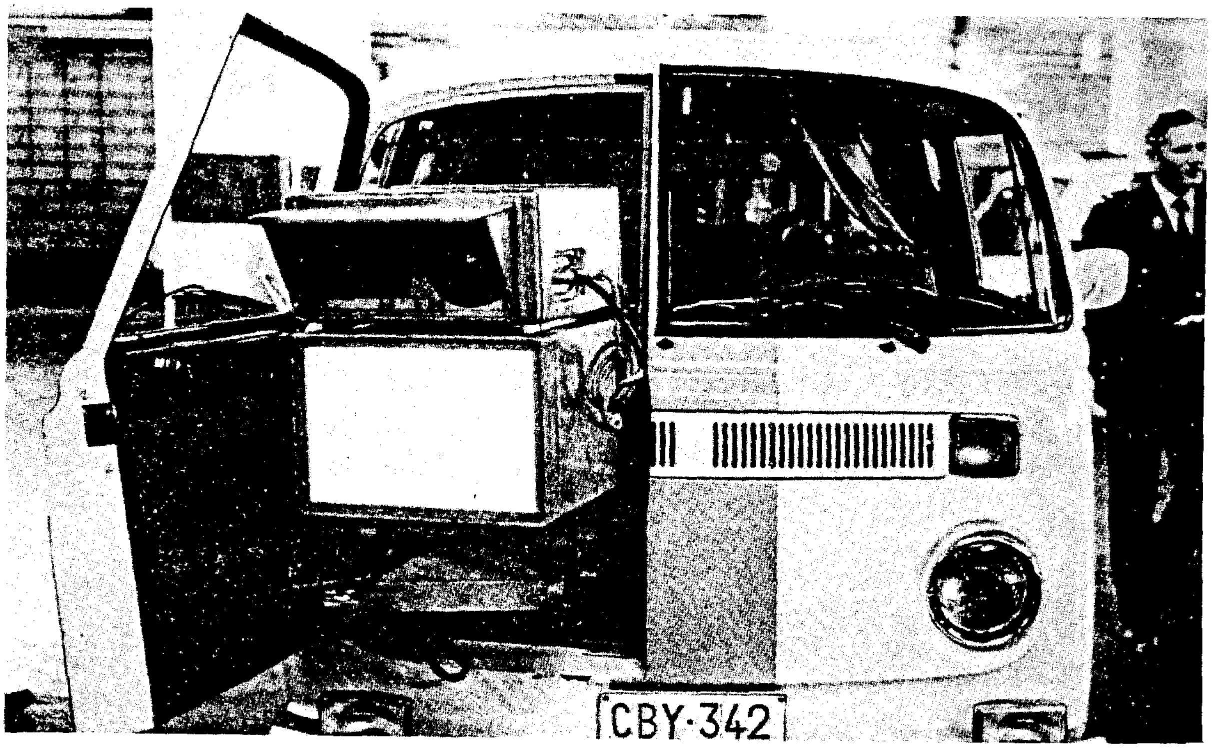
The gendarme with the equipment (two are normally used at night in Belgium) has several functions. He moves the vehicle and the radar system from location to location, according to the patrol plan. He sets up the equipment, performs calibration checks, reloads film, and witnesses its operation. Also, his presence provides security for the equipment. When on radar duty the gendarme does not normally stop vehicles in violation of the speed limit.

a. Rear view of van.

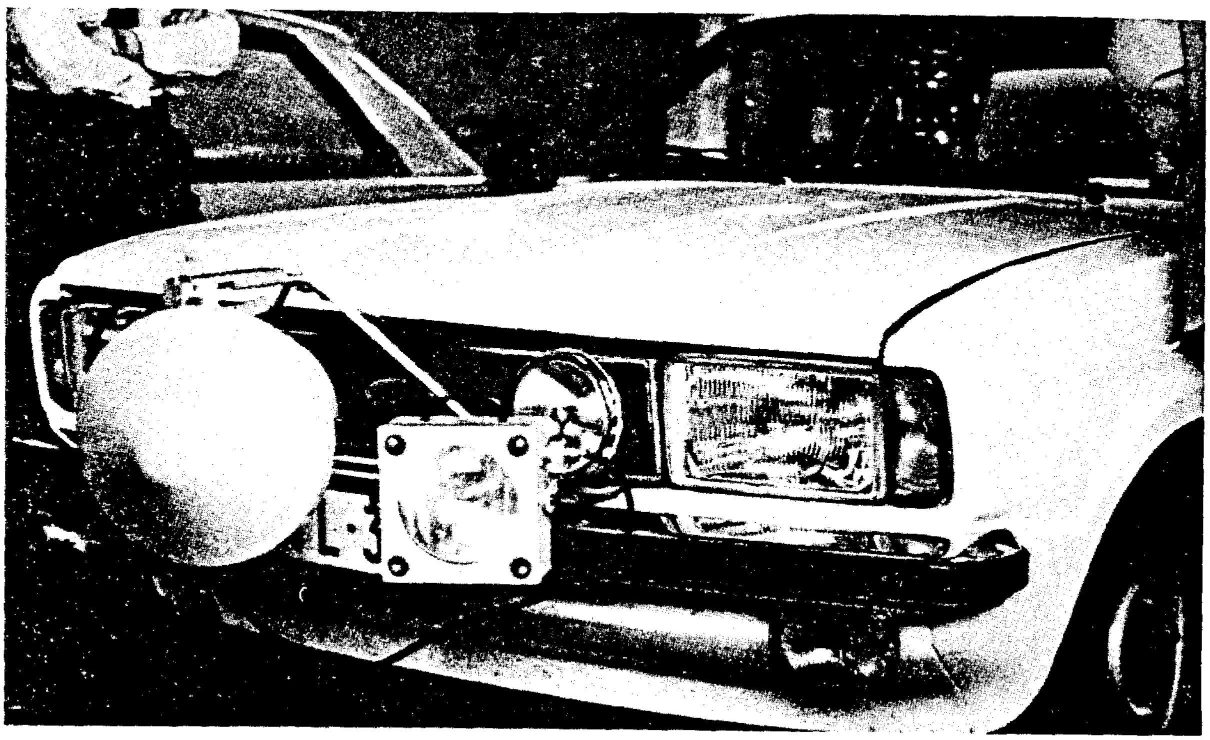


b. Interior of van.

FIGURE 11. USE OF RADAR IN UNMARKED VAN IN ROTTERDAM.



a. Early Multanova mounted in van.



b. Modern Multanova on front of cruiser.

FIGURE 12. EXAMPLES OF MULTANOVA SYSTEMS IN BRUSSELS.

4. Moveable, Unmanned photographic systems: Figure 13 shows a mobile system similar to several observed in Europe, especially in the Netherlands. The system shown was assembled by the technicians of the Police Force of the City of Haarlem, Netherlands. It is basically a self-contained Traffipax Model IV/R, with the MESTA 204 DD cross-the-road radar, Robot camera, and flash. Batteries and battery charger are also located in the trailer.

In operation, the trailer is towed to the site by a patrol vehicle and parked parallel with the curb line. The trailer is unhitched and the door on the downstream side is opened, exposing the system (see Figure 13a). The system is turned on, its calibration checked, and it is ready for automatic operation. The officer may stay with the equipment, but more frequently he may cruise in the vicinity or observe it from a nearby vantage point, for security reasons.

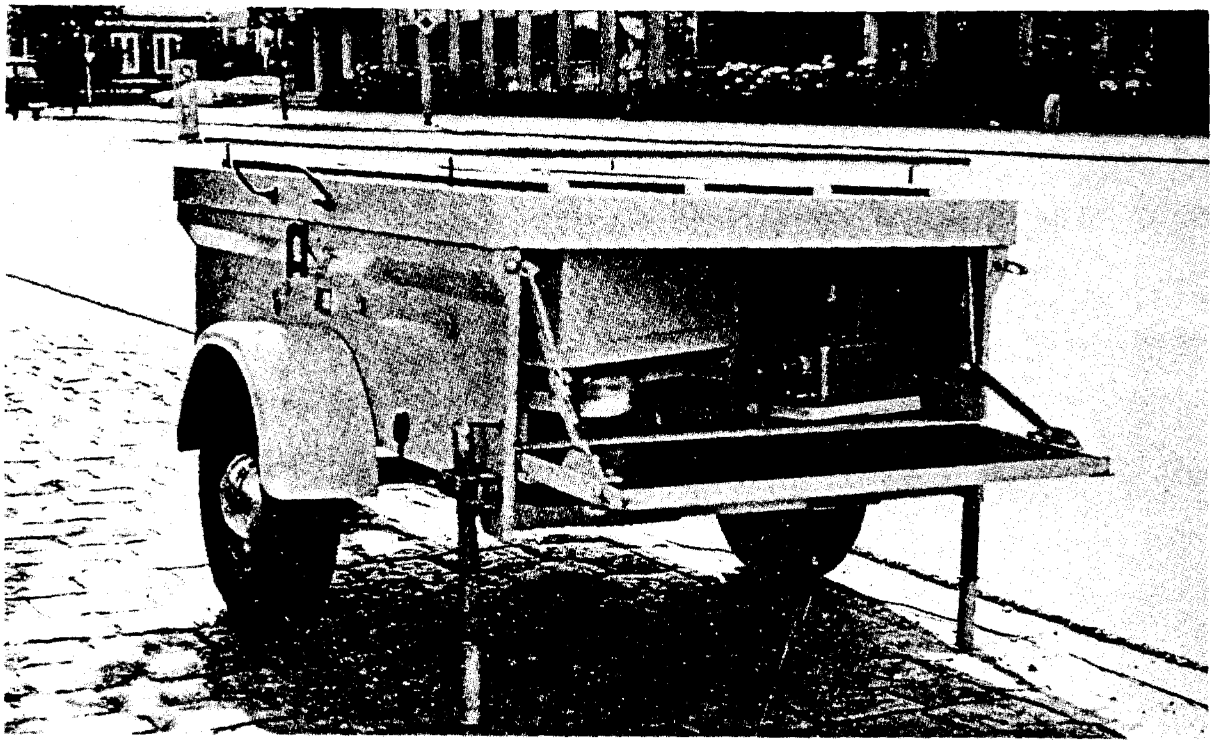
The advisory sign in Figure 13b is experimental. It is connected to, and controlled by, the Traffipax system. It can be placed several hundred feet down the road, and used in at least two ways: (1) simply as an information device, notifying each passing motorist of his speed; or (2) as an indicator of a speed violation, notifying the offending motorist that he has been detected and will soon be receiving a letter about the violation from the police.

5. Fixed, unmanned, fully automatic operation: The ultimate in automated systems are installed at key locations where speeding is of major concern. Such systems, often utilizing oversized film magazines and direct power line connections, may operate for a day or longer without attention, needing only periodic film collection and replacement.

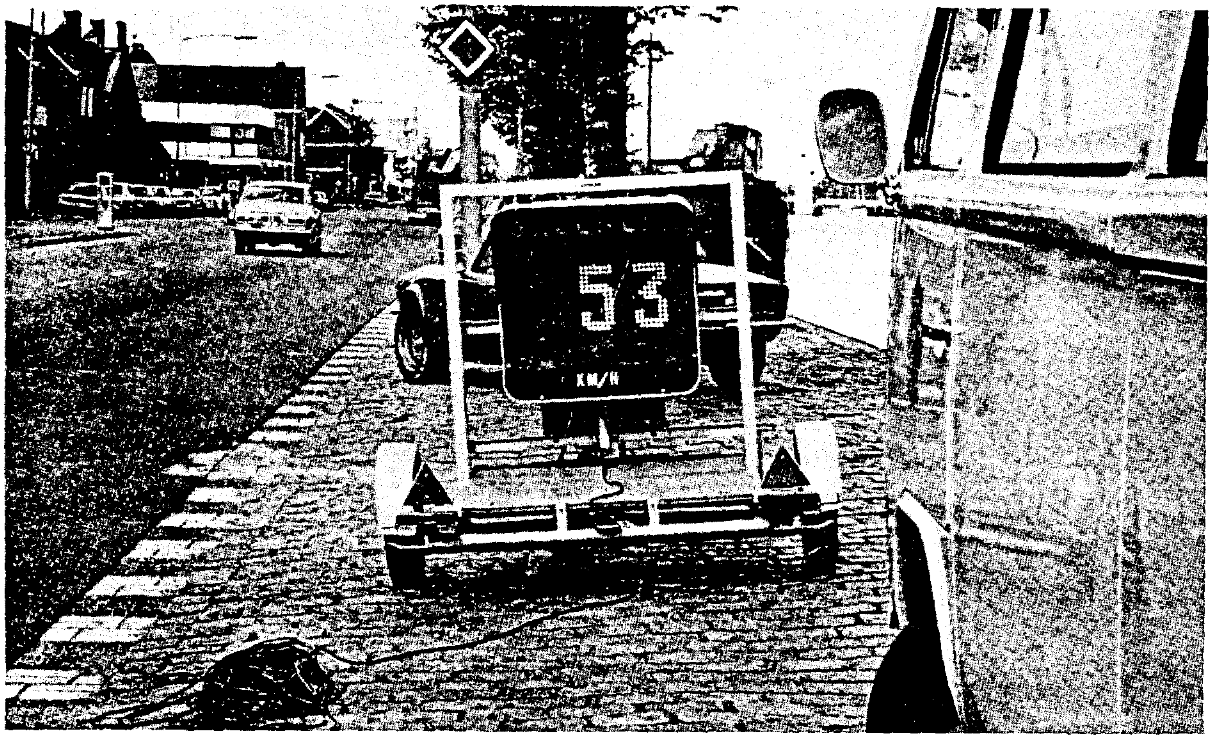
In practice, it is common to install cabinets at a number of locations, and to rotate just a few radar systems among the cabinets. Thus, most of the cabinets are dummies at any given time; the identity of the active cabinets is not known to the motorists. For example, the Holland National Police have set up 7 cabinets, among which 3 Gatso systems are rotated. In the City of Zurich there are 21 cabinets and 3 Multanova systems; an additional 21 cabinets and 4 Multanova systems are installed in the Canton of Zurich (outside the city).

Perhaps the best known automatic installation is the Multanova system at the Elzer Berg in West Germany (Figure 14). It is on an autobahn (freeway) between Frankfurt and Cologne. Although the West German autobahns generally have no speed limits, certain hazardous areas do have them. The particular location in question is a 7.2 km (4.5 mile) downgrade from a small mountain (berg) near the town of Elz. It is not overly steep (about 5%), but is somewhat winding. The combination of low downgrade truck speeds, high automobile speeds, and poor sight distance made it the most hazardous section of autobahn in West Germany. This section of downgrade averaged about 300 accidents per year; resulting in some 80 injuries and 7 fatalities per year.

The countermeasure actions were of several types. Speed limits of 100 km/hr were set for the downgrade section (40 km/hr for the right lane). A special warning sign was installed at the crest (Figure 14a,

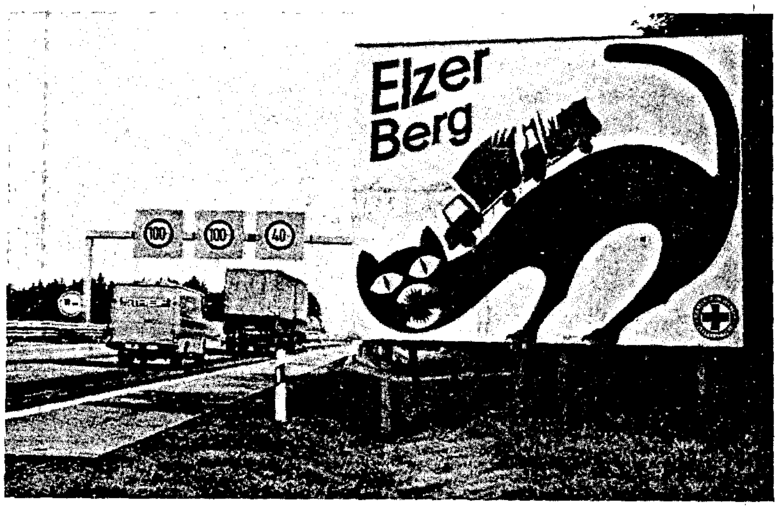


a. Trailer-mounted Traffipax IV/R.



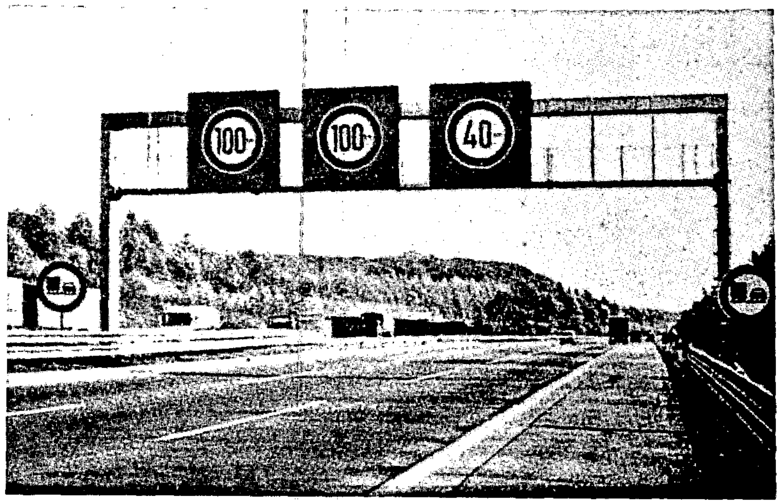
b. Downstream advisory sign.

FIGURE 13. FULLY AUTOMATIC OPERATION USING TRAILER.



a. Approach to the Elzer Berg.

b. Sign bridge on the Elzer Berg.



c. Rear of sign bridge on the Elzer Berg.

FIGURE 14. FULLY AUTOMATIC MULTANOVA SYSTEM ON WEST GERMAN AUTOBAHN.

Lower photo courtesy of Zellweger Uster, Ltd., Uster, Switzerland.

featuring an internationally understood black cat. Four sign bridges reminding drivers of the speed limits were placed at about 2 km intervals (Figure 14b). And, with great publicity, Multanova Model 4F radar systems were installed behind the speed limit signs, one for each lane of traffic (Figure 14c).

The actions were very effective. Most motorists obey the speed limit; those who continue to speed rarely exceed 120-130 km/hr (as opposed to the 150-160 km/hr speeds and more that are not uncommon on the autobahns). Yet, the radar systems do record violations. In 1978 there were 63,000 violations recorded by the systems, which operate 24 hr a day, every day. Fines collected from these violations amounted to 5.1 million DM (about $3 million, U.S.). And, in 1978, there were only 19 downgrade accidents, involving 5 injuries and no fatalities.

Aside from the unique features of the Elzer Berg just described, the other extremely important aspect of such fully automatic operations is the means of processing the filmed information. The major problem faced by every enforcement agency contacted that used automatic photographic equipment was the paperwork associated with the tremendous volume of violations recorded. Because these systems document every violation (relative to a predetermined threshhold), rather than just selected violations, the number of cases can easily overwhelm the capabilities of the law enforcement agencies.* Most agencies quickly learned that such equipment could only be deployed a few hours a week without creating unmanageable backlogs.

The same results initially plagued the police of the State of Hess (where the Elzer Berg is located). Now, a special processing unit of the police is used. After the reels of film are developed, a police officer examines the film negatives using a microfilm reader. He dictates pertinent information from the film to a typist, who enters it into a word processing system. Thenceforth, all steps are automated. Computer processing identifies the owner and address, and violations are automatically typed (with the pertinent evidence described) to each violator.

* For perspective, data on U.S. travel speeds shows that 60% of the vehicles may be in excess of 55 mph, and 20% in excess of 60 mph, in many states.[4]

IV. CONSTITUTIONALITY AND LEGALITY ISSUES

The legal issues surrounding the use, or potential use, of "automated" speed detection devices are quite complex. However, to discuss fully the legal issues in a rigorous manner is beyond the scope of this report. Instead a summary is given in this section of the U.S. research regarding these very important issues. The summary is not designed to provide legal advice. Rather it should be of use by public safety officials and other law enforcement planners as a guide to permit them to identify problem areas for discussion with their legal counsels.

In 1967, Fisher[15] published an extensive discussion of the legal aspects of speed measuring devices. This report covered various systems and their development, including three manned systems incorporating photography (Photo-Speed Recorder, Photo-Traffic Camera and Foto-Patrol), which have since passed from prominence. The report also discussed such items as the use and admissibility of scientific evidence in law enforcement, judicial notice, testing for accuracy, qualifications of speed enforcement officers, identification of vehicle and driver constitutional aspects of scientific speed measurement devices, and speed traps.

Fisher's discussion is basically limited to a brief summary of three court cases, one involving each of the three systems: Commonwealth v. Buxton (1910) 205 Mass 49, 91 NE 128 (Photo-Speed Recorder case); People v. Hildebrandt (1955) 308 NY 397, 126 NE 2d 377, 49 ALR 2d 449 (Photo-Traffic Camera case); and People v. Pett (1958) 13 Misc 2d 975, 178 NYS 2d 550 (Photo-Patrol case). A summary of these cases is also given by Goger.[16]

The speeding convictions in each of the three cases were sustained upon evidence derived from the photographs taken of the rear of each of the speeding vehicles. The Hildebrandt decision was later appealed to a higher court, which reversed the conviction on the basis that the case did not clearly establish the requirement for identification of the speeding vehicle's operator sufficiently for prosecution of speeding. In other words, the assumption of vicarious liability was rejected by the higher court.

Fisher concluded that unless this type of system has an officer in attendance to arrest and identify the driver on the spot, the same deficiency in proof would prevent its effective use, based on the appealed Hildebrandt case.

Much of the literature published in the late 60's and early 70's on the legal aspects of speed measuring devices centered on manned radar systems and their usage. However, experiments were conducted in the early to mid-70's to determine the effectiveness of a proprietary unmanned system, called Orbis III. The system consisted of roadway sensors, a speed measuring device, and a camera and flash unit. The camera, using infrared film and an infrared flash, automatically photographed the front of vehicles determined to be traveling faster than a preset speed. The photograph included the vehicle and its license plate; the faces of the front seat occupants; and the date, time, location, and speed of the vehicle. These experiments spurred the publication of a number of reports dealing with the legal issues and potential constraints associated with the use of this type of speed measuring device.

In late 1973, Glater[17] reviewed the legal basis for certain potential challenges to the use of unmanned detection and photographic devices such as the Orbis III. The report focused on three aspects of the device's legality. The first issue was whether the device's operation violated the individual's right to privacy. The report reviews several types of right-to-privacy issues. Those based on the U.S. Constitution involve looking at the 1st, 3rd, 4th, 5th, and 9th Amendments. The test of unconstitutionally involves whether Orbis affects any "fundamental rights" or "unreasonably invades a protected zone of privacy." The author concludes that driving is already heavily regulated by the government (indicating that a strong public policy exists), that driving on public roads is not private in nature, and that, therefore, Orbis is permissible.

The test concerning the 4th Amendment's guarantee against unreasonable searches and seizures asks if Orbis "invades an area reasonably expected to be free from public exposure" and, thereby, violates the privacy rights of the driver (and occupants) when it "searches" and "seizes" his (their) identity. The author argues that the driver is already knowingly publicly exposed, visually, in his glass-enclosed vehicle, so that the taking of a photograph is not an unreasonable search and seizure.

Also analyzed are Orbis' impacts on the 1st Amendment's freedom of association. This reasoning contends that passengers will stop associating with drivers of cars on Orbis-patrolled roads. The harm lies in the unedited snapshot of car, driver, and occupants. The author offers two U.S. Supreme Court cases which in effect hold that Orbis must cause a "specific <u>present</u> objective harm" and not a specific or general <u>future</u> harm. In other words, the harm must be actual, not hypothetical, before relief may be obtained in the courts.

The second issue analyzed is that of equal protection. Basically, the concept relative to Orbis involves the machine's 1-lane-at-a-time, 4-second-rewind traits; that is, some speeders escape detection. Legally to be an equal protection violation, Orbis must manifest an intentional and clear discrimination against an individual or a class of individuals. The author concludes that it does not.

The admissibility of Orbis "testimony" into evidence (the third major issue) involves two elements: (1) it must be an <u>accurate</u> representation of the scene it contains, and (2) it must be an <u>authentic</u> representation of the scene it contains. The traditional legal view is that <u>any</u> photograph is inadmissible without the corroborative testimony of a human being that these two elements are present. The author suggests that the Orbis system "speaks for itself" (i.e., needs no corroboration.) He acknowledges the weakness of the argument, however, and suggests that the solution involves convincing the state legislatures to pass a law allowing photos from Orbis-type systems.

In 1976, Dreger and Hawkins[18] described an Orbis III speed enforcement demonstration project in Arlington, Texas. The authors summarized the legal aspects of two problems associated with the court presentation of Orbis III cases--the issuance of citation or warrants requiring court appearance, and the introduction of photographs into evidence. Included in the discussion of the first problem were such issues as the methods usable to ensure the defendants appearance in court, and the vehicle owner's claim of privilege. Included in the discussion of the second problem were such additional legal issues as establishment of judicial notice through proof of scientific validity and reliability of the system by expert witnesses; proof of proper calibration and maintenance of the system by police officers; use of sound evidentiary procedures in the production and possession of the photographic evidence; invasion of right to privacy; and rights of the defendant to cross-examination. The authors concluded that there are no unique problems associated with Orbis III or its photographs which should preclude their being accepted as valid evidence of speeding violations, and that if a photograph is admitted as evidence, the court must decide if the defendant and the driver of the vehicle are one and the same person.

The Highway Safety Research Institute (HSRI) studied the legal issues associated with speed detection systems as part of its analysis of the potential legal constraints that might be encountered in the implementation of selected countermeasure programs.[19] Part of this work focused on the legal issues associated with automatic systems, to detect and identify vehicles exceeding preset speeds. The Orbis III system was used as an example in the analysis.

In 1979, Ruschmann et al[20] also issued a report on the assessment of the legal feasibility of vicarious liability speed-law statutes. It concerned the legal issues that might be encountered with states that impose criminal or civil liabilities on the owners of vehicles observed in violation of speed laws, in the absence of information about the identity of the actual drivers. The absence of driver identification would result where only the rear of the vehicle is photographed, or where the camera is "aimed low," perhaps for right-to-privacy reasons, so that only the area around the front license plate position is photographed.

Liability for speeding may be criminal, quasi-criminal (where a city traffic violation is not actually a "crime"), and/or civil. Criminal liability requires in most cases formal charges, a jury trial (if desired), benefit of counsel, and the right to confront opposing witnesses. Quasi-criminal liability usually does not require these things. In fact, the number and degree of these rights afforded an arrestee vary directly as a function of seriousness. Understandably, the presence of vicarious liability in more serious offenses, such as speeding coupled with a hit-and-run, is less likely.

In some states, however, minor traffic offenses are being decriminalized. This opens the door to passage of vicarious liability statutes because penalties involve nothing more than minor fines and point assessments. So far the most popular vicarious-liability vehicular offense is a parking violation.

Civil actions are generally viewed as being less serious than criminal actions because penalties do not include incarceration. Civil sanctions ordinarily involve monetary penalties, forfeitures, and liens. (Liens may be monetary or may prohibit re-registration of a car.) Legally, the jeopardy of the defendant is viewed by the courts as less in these cases and vicarious liability is, therefore, more likely to be constitutionally (due process) permissible.

Ruschmann et al[20] concluded that civil statutes designed to impose vicarious liability on the owners of vehicles observed in violation of speed laws are legally feasible. On the other hand, criminal statutes directed at a vehicle owner that provide for any form of incarceration would probably not be legal under either a vicarious liability or a presumptive basis. However, criminal statutes providing only for fines might be legal under a vicarious liability basis in some states provided it can be postulated that an owner can have considerable control over the actions of other drivers of the vehicle. If this relationship between owner and driver cannot be postulated, then it is unlikely that vicarious liability could be imposed.

They also conclude that the creation of decriminalized vicarious liability statutes for speeding violations would eliminate many of the objections posed by criminal statutes. This is possible if no jail penalties and no violation points are assessed against the owner's driving record. The resulting decriminalized statute would resemble a pure civil statute, but would not have the flexibility of a pure civil statute. The civil statute could constitutionally provide for either fines imposed directly on the vehicle owner, or liens against his vehicle. Current vehicle certificate of title and annual vehicle registration procedures in most states, with some modifications, could be used in conjunction with these liens to enforce the penalties. Such vehicle-offense-related liens could be used to constrain the free sale or transfer of vehicles cited for speed-law violations. Certificate of title notices and/or title records could also be used as a basis for the ultimate seizure and sale of vehicles owned by repeated speed-law violators who refused to satisfy the lien penalties.

In 1979 another report[21] was prepared by HSRI concerned with accident countermeasure legal constraints, which contained a preliminary assessment of the use of speed measuring devices. The report covers a variety of such devices, the legal issues that can arise from their employment, the potential constraints that derive from those legal issues, and the significance of those constraints. The potential constraints include:

* Establishing the scientific validity and reliability of devices not based on the same principles as the judically noticed radar speedmeter;

* Dealing with the existence of state statutes prohibiting "speed traps," which might preclude the use of certain devices;

* Obtaining evidence relating to such factors as road conditions, weather, traffic, and time of day when necessary to prove a violation of a basic or prima facie speed law; and

* Identifying from data provided by a remote-observation device the offending driver so that action may be taken against him.

Another section of the report discusses approaches that can be employed to remove or resolve these constraints. A final section discusses the general feasibility of speed measuring devices in light of the identified constraints, presents an assessment of the approaches suggested for resolving those constraints, and makes recommendations concerning the employment of the devices.

Ruschmann et al[21] conclude that constitutional authority exists for both the regulation of vehicle speeds and for the employment of electronic and mechanical speed measuring devices. The use of these devices is restricted by state statutes as well as rules of evidence governing the admissibility of the device data in court proceedings. The constitutional and statutory procedures that govern the prosecution of speed violators also restrict the use of data obtained from these devices.

The effectiveness of automatic speed detection systems that do not identify the driver of a speeding vehicle would be severely limited in determining speed violations. Under current laws governing the prosecution of speeding violators, a conviction (or even initiating a prosecution in some instances) might not be justified from data produced by an automtic system if the driver cannot be positively identified.

Two strategies are possible under these constraints. One alternative is to hold the owner vicariously liable for the offense; the other is to use presumptions that force the owner to identify the driver. Both of these alternatives require modification of existing laws. However, even if modifications are made to adopt these approaches, vicarious liability and owner-driver presumptions are likely to be contested on constitutional grounds, especially in states where speeding is characterized as a criminal offense.

Two possible effective ways exist to use data from an automatic system that does not identify the driver. One is to pursue flagrant speed-law violators for the purpose of sanctioning them by issuing warnings. Police and driver licensing authorities are not limited to using traditional sanctioning modes against drivers or owners. Warning letters to registered vehicle owners--especially if the owners are commercial enterprises that employ drivers for business purposes--might have a significant deterrent effect. The second way, although much weaker than the first, would be to use the data to promote public awareness of speed-law enforcement.

V. PUBLIC ACCEPTABILITY ISSUES

The public acceptance issues pertaining to the use, or potential use, of ASE devices in the United States also are many-faceted and complex. Again a rigorous discussion of this subject is beyond the scope of this report. However, a summary is given below of the United States and Canadian research regarding the public acceptability issues.

As stated earlier in this report, Orbis III systems were used intermittently in the United States in a series of research experiments between late 1973 and early 1976. These experiments were carried out in West Orange, New Jersey, and Arlington, Texas. Unfortunately the brief use of the Orbis III in the United States did not allow sufficient time for public acceptance issues to develop and be resolved.

The Canadian experiences with automatic speed detection systems did, however, result in some public acceptance issues being raised in that country.[22]

About 13 years ago the Quebec Provincial Police installed some fully automatic Multanova systems on the Provincial highways. In normal use, the front of the speeding vehicle was photographed because the driver could then be identified from the photograph. The license number of the speeding vehicle was recorded from the photograph and was used to locate the owner. A speeding citation was then mailed to the owner of the vehicle. At that time, all speeding offenses required a court appearance for the fine to be levied. The photograph was used as evidence in court and was corroborated by the police officer's testimony. (Although the units were fully automatic, they were attended by officers at least 75% of the time.)

The Quebec Provincial Police were very much in favor of using the units. They felt the equipment was not only accurate, but also highly reliable, having only minor problems. Some of the police did abuse the use of the system by concealing the units and using them on roads with unreasonably low speed limits.

After 4 to 5 years, the use of the units was challenged in the courts with arguments based on the issue of invasion of privacy and on the abusive use by the police. Many drivers were embarassed by being photographed with other vehicle occupants at certain times and locations. These challenges resulted in the courts banning the use of the photographic capabilities of the units. The units have been used for speed enforcement since that time but without the camera.

Currently, the police officer has to personally stop a speeding violator and issué the citation to him at the time of the infraction. No photographs are allowed to be taken. The violator can now either contest the charge in court or go to a designated bank or courthouse to pay the fine. It is the current opinion of the Quebec Provincial Police that photographic speed detection devices are not likely to ever be used in Quebec unless public opinion about the use changes.

The Canadian experiences with the use of frontal photography and the attentant challenges of this approach on the basis of invasion of privacy issues guided NHTSA's/MRI's decision to concentrate on ASE devices that photograph the rear of violating vehicles. If an ASE device were to be used in U.S. speed enforcement, a photograph would be taken of the rear of the vehicle to identify only the license plate. The vehicle occupants would not be identifiable with this approach. Hence, the privacy concern of photographing the vehicle occupants would not apply.

A study of the "Public Acceptability of Highway Safety Countermeasures" was recently completed by the Mathematica Policy Research, Inc.[23] Speed detection systems, including ASE devices, were included as some of the countermeasures investigated.

The research design for the study of public acceptability consisted of three complementary research procedures: focus-group discussions, special interest case studies, and general public survey. The focus-group discussions were employed in the design and pilot stages of the study to:

* Identify and define relevant variables that should be investigated;

* Help develop questions worded so that survey respondents would be able to understand and answer without difficulty, and that would at the same time measure the relevant variables; and

* Develop hypotheses concerning the relationship between these variables to be tested by the survey.

Nineteen focus-group discussions, consisting of 6 to 11 persons per group, were held in five U.S. cities.

Members of special-interest groups often have access to highway safety policy makers and may be in positions to facilitate or thwart countermeasure implementation. Hence, the special interest case studies were conducted in an effort to obtain expert opinions about possible differences in perceptions of these highway safety countermeasures. Structured interviews were conducted with individuals selected from three major types of groups within each of 10 states (one state was drawn randomly from each of the 10 NHTSA regions). The first major group consisted of representatives of state highway safety departments, state police, and police chiefs associations. These officials were selected for their safety planning and enforcement activities from a state basis. The second group consisted of members of state bar associations and state civil liberties union. These individuals were involved to obtain their views on the legal and constitutional right issues raised by some of the countermeasures. The third group consisted of members of particular consumer or business interests such as the American Automobile Association, leading state insurance companies, state trucking associations, and state automobile dealers associations.

The general public survey was conducted to obtain measures of general public views about highway safety issues and proposed countermeasures. The survey was conducted by telephone and involved three subsamples, each of approximately 500 respondents. Each of the subsamples in the survey constituted a probability sample of the universe being surveyed (the U.S. population of age 18 or older). A different questionnaire was used for each subsample. Also, a randomized procedure was used to select the respondent in each household called.

Of the three research procedures employed in the study, only the general public survey was based on a statistically predictive sample and yielded quantitative data which could be interpreted as reflective of general public opinion on specific issues. Both the focus-group discussions and the special interest case studies resulted in qualitative information providing a broad perspective about the kinds of issues and concerns which may be associated with countermeasure implementation. The results of the focus and special interest groups cannot be generalized as representative of acceptability concerns in the general population.

The public acceptability of speed detection devices was one of the subjects investigated, but not with all the individuals contacted in the study. The subject of speed detection was broached with slightly more than half of the focus-groups, with each participant in the special interest case studies, and with only one of the subsamples of the public survey. The detection devices discussed were an automatic speed enforcement device, speedmeter measurements, radar and vascar. The Orbis III device was used as an example of an ASE device during the focus-group discussions; the Multanova and Traffipax devices were used as examples of ASE devices during the special interest case studies. No specific ASE device was named during the general public survey.

It is important to realize that the focus-group discussions and the special interest case studies were informal, open-ended discussions. No attempt was made to supply respondents with additional information not included in the prepared countermeasure descriptions, or to correct any misunderstandings which respondents may have had. As a result some of the judgements and reactions may have been based on misunderstandings of the issues. This was particularly the case in the discussion of the ASE device. The description of the Orbis III (as well as the Multanova and Traffipax) was vague with respect to how a photograph would be taken. Some respondents interpreted "a photograph of the car" to mean a photograph of the driver. This interpretation was incorrect from the design standpoint of the Multanova and Traffipax devices. The interpretation was correct from the design standpoint of the Orbis III; however it was incorrect from an enforcement implementation standpoint. Thus, with these incorrect interpretations of the devices and their potential use, invasion of privacy issues were again raised.

The general public survey regarding speed detection and deterrence, by nature of design from the focus-group discussions and special interest case studies, was also burdened with the concern of the invasion of privacy issues. The respondents were asked during the structured telephone interviews if they opposed the use of an automatic camera device to identify who was actually driving the car and if they thought this form of identification was an invasion of privacy. Thus, not even the results of the general public survey can be used to assess the public acceptability of using ASE devices that photograph only the rear of violating vehicles. It is unfortunate that the misinterpretation of the use of ASE devices conveyed to participants in the public acceptability study prevents the use of the survey results in this report. The results can only be used to reinforce the actual Canadian experience regarding the use of photography to identify speeding drivers.

The only conclusions regarding the public acceptability of ASE devices photographing the rear of violating vehicles must be drawn, therefore, from the study reported herein. Virtually no adverse public reaction was voiced during the preliminary law enforcement field testing of the four ASE devices. Only two complaints were received from motorists during the several hundred hours of law enforcement operations with the ASE devices. The state police commanders connected with the field testing felt that public acceptance of ASE devices, as tested, would depend on a good public information and education campaign. They also felt the acceptance would be enhanced if the penalty for speeding offenses detected by ASE devices was changed from a combination of fine, points and potential jail sentence to simply a fine--similar to a parking ticket.

VI. SUMMARY OF ENGINEERING FIELD TESTS AND RESULTS

Six European-manufactured ASE devices were tentatively selected for preliminary shakedown and field evaluation in the U.S. These devices were the: Gatso Mini Radar Model MK4, Multanova Model 4FA, Traffipax Type V/R, Truvelo Model 4, Amdar Radar, and Optoelectric Speedcontrol SM3. However, only the first four of these devices could be obtained from the manufacturers in time for the testing. For brevity, they will often be referred to simply as the Gatso, Multanova, Traffipax, and Truvelo, respectively.

This chapter contains two parts. The first describes the importation, engineering adaptation, and acceptance testing of the four ASE devices. It also notes some of the initial difficulties and problems encountered with the devices. The second part presents a summary of the engineering field tests conducted and their results.

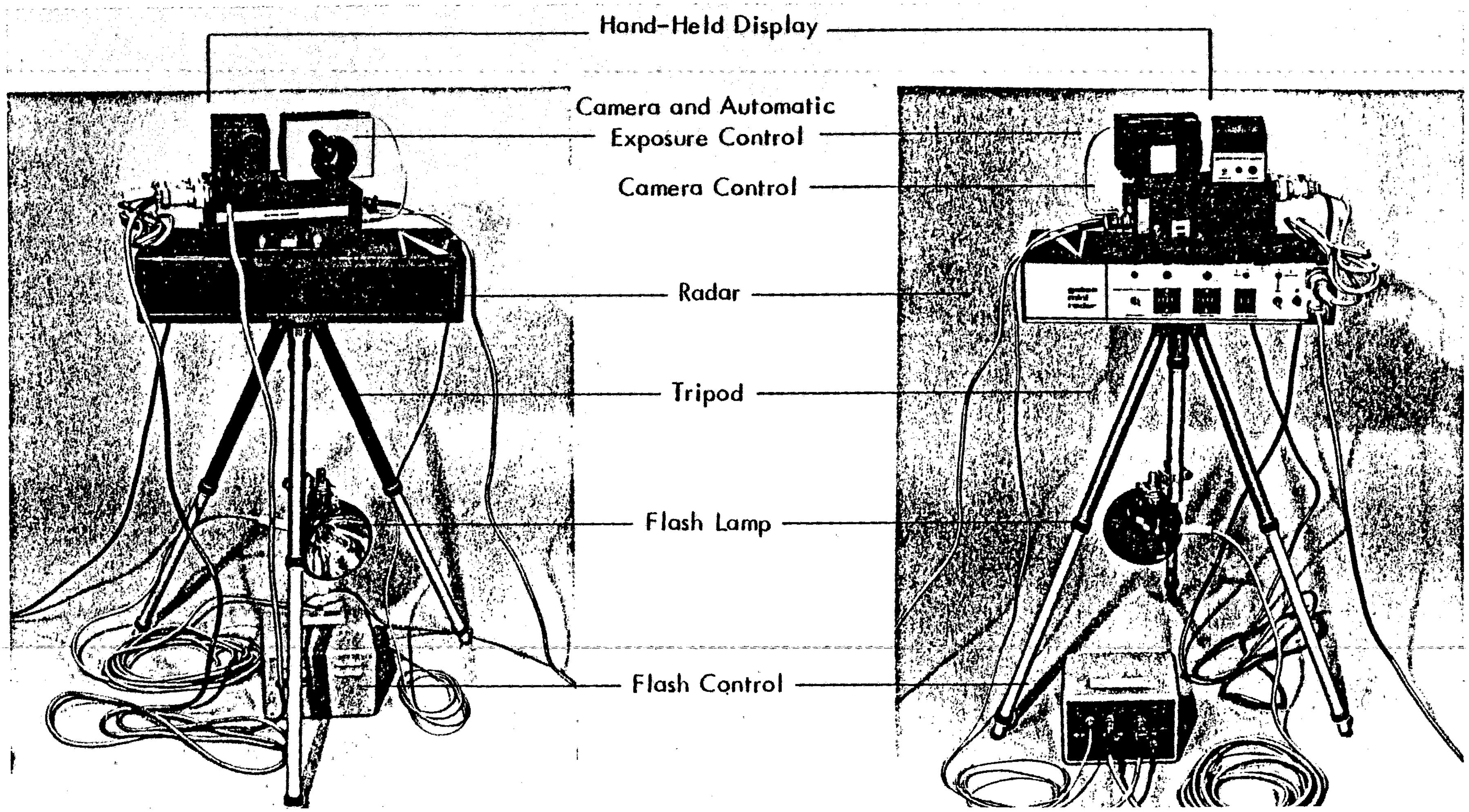
A. Importation, Engineering Adaptation and Acceptance Testing of the Selected ASE Devices

The importation, engineering adaptation and the acceptance testing of each of the four selected ASE devices are discussed in this section. The initial problems encountered with each device are also highlighted.

1. Gatso Mini Radar Model MK4: This is a portable device which incorporates a tripod-mounted radar made by James Scott, Ltd., of Scotland; a West German Robot data camera; and a Dutch Gatsonides data and control unit. Figure 15 illustrates a typical tripod-mounted arrangement of the Gatso system, showing all of its components. The photographic subsystem (composed of the data and control unit and its camera) was purchased from the Dutch firm. The radar subsystem was leased from James Scott and imported into the U.S. under a Temporary Importation Bond (TIB). Equipment orders for both subsystems were placed at the same time; however, the Scott radar subsystem was received about 1 month after the other components. This time lag delayed the acceptance check-out of the Gatso Mini Radar.

Attempts to check the operational status of just the photographic subsystem were thwarted by a lack of circuit diagrams for the data and control unit and because the equipment could not be operated independently of the Scott radar without circuit modifications. Additional circuit diagrams for the Gatso components were requested from the manufacturer. Once the Scott radar was received, the Scott/Gatso system was assembled and bench tested. The photographic subsystem still would not operate. A comparison of the Gatso components with the circuit diagrams supplied in response to the special request showed discrepancies in the wiring. Once these and other minor problems were corrected, the photographic subsystem was found to operate as expected. The Scott/Gatso system was then acceptance tested using actual traffic flow on a city street. Problems were then found with the Scott radar, some of which are listed below:

> In the Recede mode, the radar rarely detected <u>any</u> vehicles, approaching or receding.



a. Front View

b. Rear View

FIGURE 15. TRIPOD-MOUNTED GATSO SYSTEM.

- In the Approach mode, the radar detected a majority of <u>all</u> vehicles, approaching and receding.

- In the Approach mode, about 1/4 of the vehicles in violation of the set speed were not detected, even if totally isolated.

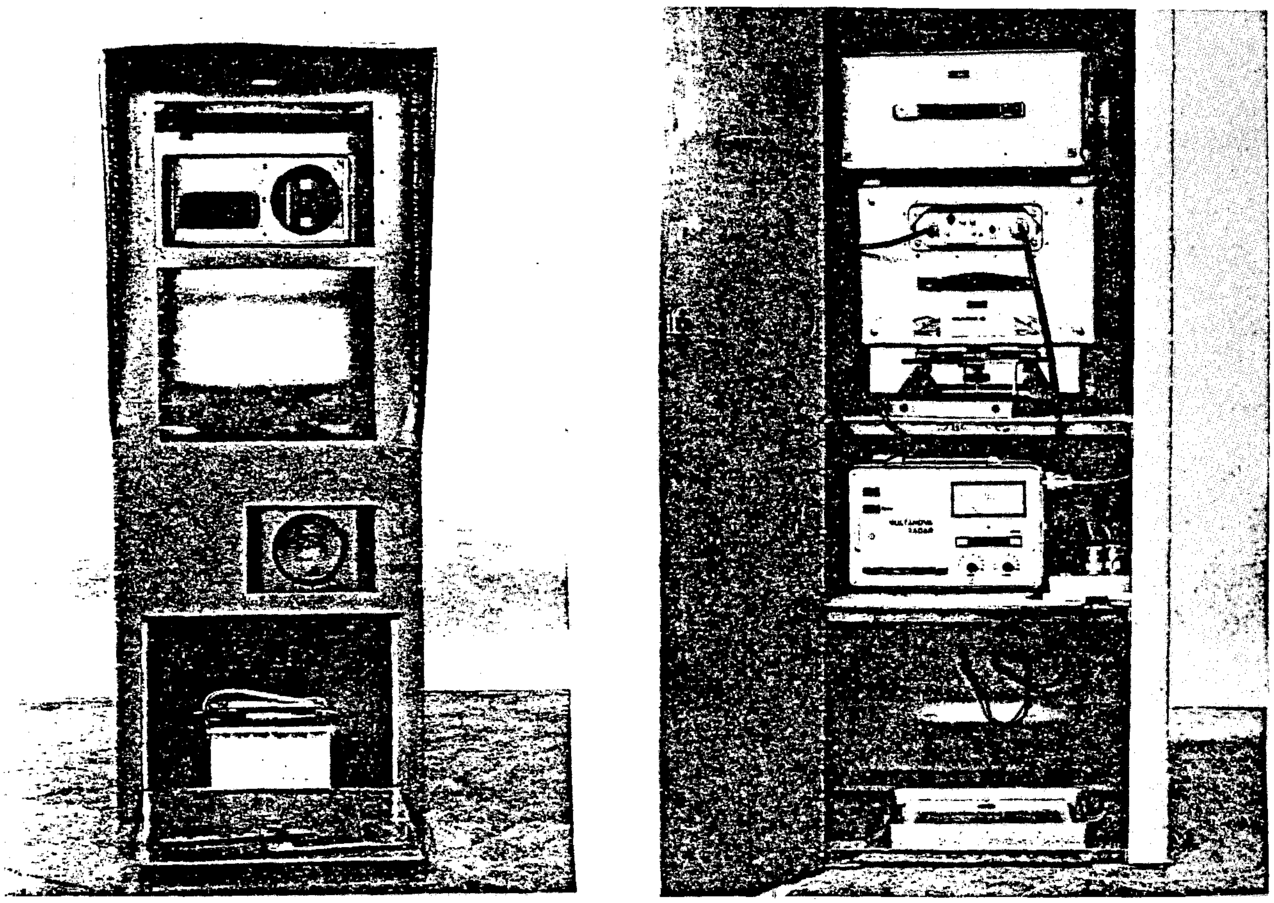
- Occasionally, individual vehicles were counted more than once in the total count of vehicles and/or in the count of violators.

- All of the problems noted appeared to be independent of whether or not the camera unit was connected and/or used.

These problems seriously impaired the operation of the Scott radar and were documented and conveyed to James Scott, Ltd. Further communications with Scott identified a faulty direction sensing Doppler signal amplifier printed circuit board. A replacement board was ordered from the manufacturer, imported into the U.S. under a new TIB, and installed in the radar unit. The unit was then briefly tested in actual traffic and found to operate as expected.

2. <u>Multanova Model 4FA</u>: This is a Swiss device designed for installation in a roadside cabinet for fully automatic, unattended operation. The Multanova system was purchased from the Swiss firm, Zellweger Uster, Ltd. The system arrived in the U.S. on schedule and cleared customs without difficulty. A representative of the Swiss firm followed the system to the U.S. and spent parts of 2 days at MRI presenting a briefing on the system operation, describing the cabinet installation requirements, and demonstrating the use of the system. After assembly of the components, the equipment was acceptance tested (without its cabinet) with traffic in both the near and far lanes of a 4-lane, 2-way city street. The system performed as expected.

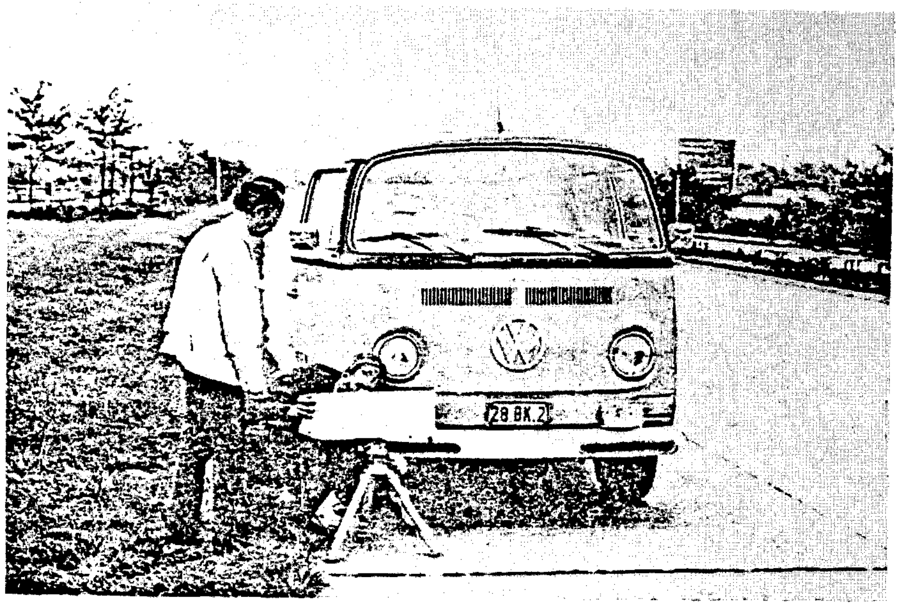
Two roadside cabinets for the Multanova system were fabricated using design drawings supplied by the Swiss firm. The cabinets were constructed so they would be light weight, yet strong enough to provide protection from accidental damage and vandalism for the electronics, power supply, and camera. The frame of each cabinet was made of steel angle iron and was covered with 1/8 in. aluminum sheeting painted grey on the outside. The front of each cabinet contained three windows covered with lexan and a small, lockable door (see Figure 16). Two of the windows were transparent and were for the photo and flash unit. The third window was for the radar transceiver and was milled to a specific thickness so it would be electrically transparent to the radar frequency of the unit. The small door provided access to the power supply (battery) compartment. The back of the cabinet contained a large access door that could be locked. Two shelves were located on the inside of each cabinet to support the various components of the device and their connecting cables. Thus, all the equipment associated with the device was completely contained within the cabinet. The base of each cabinet was designed such that the enclosure could be bolted to anchor bolts set in a concrete pad used to support and steady the cabinet.



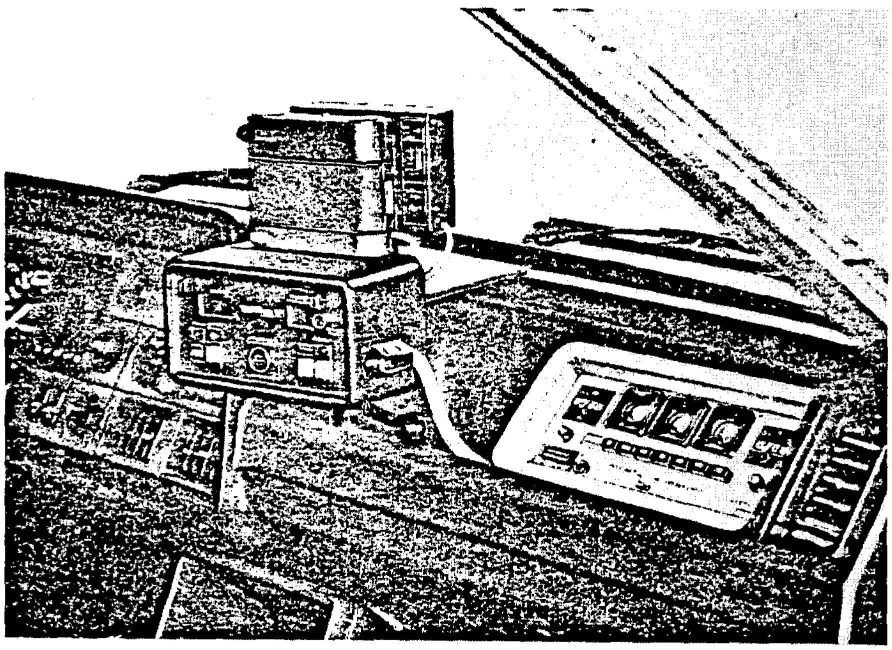
a. Front View b. Rear View (Door Opened)

FIGURE 16. MULTANOVA INSTALLATION.

3. Traffipax Type V/R: This is a West German device which uses a French Mesta radar with a Robot camera and is designed for semi-permanent mounting in a police vehicle (see Figure 17). This system is the only one of the four that was obtained through a manufacturer's representative in the U.S. This arrangement, although seemingly beneficial, resulted in some problems. Because the representative was not local (he was in Florida), this was not his full-time occupation, and he was not as knowledgeable as we had hoped, the problems were compounded. For instance, we had to incur an additional expense of issuing a letter of credit for the purchase, shipment and import duty cost. Some of the cost elements were estimated too high, which resulted in an overpayment to the representative. A long delay was encountered in receiving the proper refund. Also, it was difficult to determine, via the representative, the status of the manufacture and shipment of the device.



a. S.F.I.M. radar.



b. Control unit, data box, and camera.

FIGURE 17. TRAFFIPAX MODEL V/R.

All components of the Traffipax system were closely inspected upon receipt at MRI. A surprisingly large effort, including some electrical work associated with preparing the cables interconnecting some components, was needed before the system could be acceptance tested. The manufacturer's representative even spent considerable effort in labeling and sorting cables, connectors, and other components before forwarding the shipment to MRI.

Once the system was assembled (outside of its vehicle) it was acceptance tested near MRI's facilities and found to be operating in accordance with expectations.

The SFIM radar unit for the Traffipax had five preselected metric speed settings (60, 70, 80, 90, and 100 k/hr)* which, unfortunately, do not correspond to typically used mph speed settings in this country. The radar operators manual supplied with the device indicated that other speed settings are available on request. (This was not made known to us when we ordered the system.) We contacted the manufacturer for instructions to reset the unit to more appropriate speed settings. We were informed the device could not be altered without shipping the unit back to the manufacturer for extensive modifications. To avoid further delays, the unit was used as received even though the preselected metric speed settings were not ideally appropriate to law enforcement testing. A conversion chart relating k/hr to mph readings was made and affixed to the photographic subsystem to aid the law enforcement personnel.

The Traffipax system was installed in a government-owned vehicle following the manufacturer's instructions. The basic installation was accomplished in 1-1/2 days by an experienced technician. Thus, the system is not one that would be moved readily from vehicle to vehicle without some design changes being made.

Problems were found during the Traffipax installation with the dash mounting arrangement of the camera. A new bracket was fabricated so as to provide a clear field of view for the camera. Minor modifications were also made to two vehicle-mounted connectors that joined the radar antenna to its battery and control unit. The modifications were made to simplify the radar set-up and tear-down procedures.

4. <u>Truvelo Model 4</u>: This is a portable, non-radar device from South Africa/West Germany/England that uses piezoelectric roadway sensors and incorporates a Robot camera and special data box for automatic data recording. Figure 18 illustrates the Truvelo system tested, showing all of its components. The Truvelo system was purchased through the firm's London office. A representative of that office followed the system to the U.S. and spent parts of 2 days presenting a briefing on the system operation and demonstrating its use. After minor assembly, the equipment was briefly tested on a 2-lane, 2-way road and found to be operating as expected.

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* Equivalent, respectively, to 37, 43.5, 50, 56, and 62 mph.

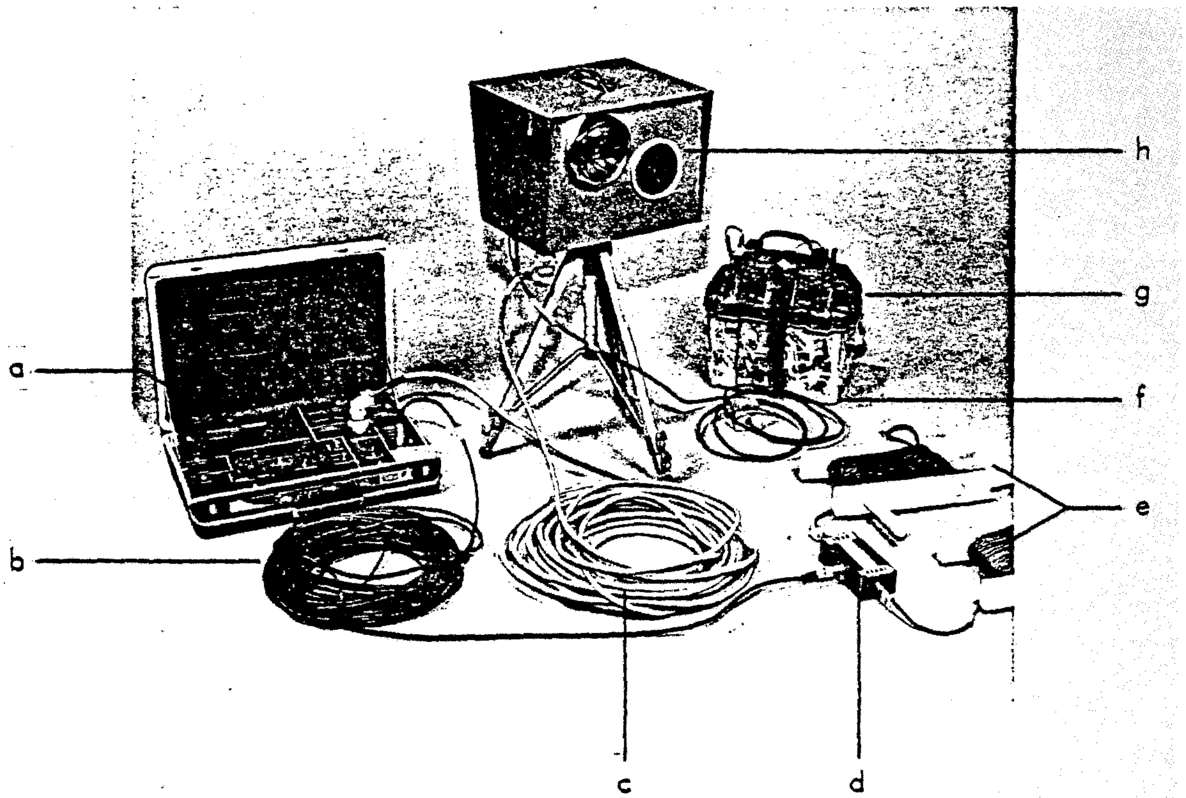


FIGURE 18. TRUVELO MODEL 4 SPEED MEASURING INSTRUMENT WITH CAMERA SUBSYSTEM.

a) Measuring Instrument
b) Input Cable
c) Camera Cable
d) Impedance Convertor
e) Coaxial Detector Cables
f) Photographic Subsystem Power Cable
g) 12-V dc Battery
h) Photographic Subsystem

Continued acceptance testing of the Truvelo system as to its functionability turned up several minor problems. These were communicated to the manufacturer. The problems and their solutions are briefly described as follows:

* The labeling on the measuring instrument indicated the unit required 220 V for recharging the batteries instead of the requested 110 V. The unit was found to be designed for 110 V recharging and was simply mislabeled.

* No recharging cables were included with the system. A recharging cable was fabricated rather than waiting for the shipment from South Africa.

* The camera came equipped with a 75 mm lens, rather than 45 mm as specified in the sales brochure. The camera locations relative to the roadway sensors described in the instruction manual were subsequently clarified as pertaining to the use of the 75 mm lens.

* It was our understanding when we ordered the system that it included an automatic exposure control for the camera. We were notified that the camera housing unit was not designed for use with an automatic exposure control. Consequently, none was supplied with the camera.

* The manufacturer's operating manual stated that the device can be built to operate in one of two different preprogrammed modes. One mode of operation requires the unit to be manually reset after it records a speeding violation. In the other mode of operation, the unit automatically resets itself approximately 1 sec after each violation is recorded. The manufacturer's operating manual states the user must request one or the other of the two modes of operation. We were unaware of this requirement when we placed the order. The unit we received was programmed to operate in the first mode described, and thus was not capable of operating in a fully automatic mode. The manufacturer in South Africa was contacted to provide us with instructions on how to modify the reset mode of the device. The manufacturer quickly responded with the required instructions. The unit was easily modified as indicated and briefly tested to confirm that it automatically reset itself after a speeding violation was recorded.

Finally, we were required by the FCC to obtain special licensing of the devices using radar before tests of these units could be conducted. A recent reorganization of the FCC made it difficult to readily obtain the needed licensing. It was necessary to obtain two renewals of Experimental Special Temporary Authorizations (ESTA's) before we were granted the appropriate licensing. Each ESTA was valid for only a few months, but allowed for the experimental testing of the radar units in the areas we specified.

B. Summary of Engineering Field Tests and Results

The engineering field tests were conducted by MRI in the Kansas City area. The purposes of these tests were two-fold--to obtain operational familiarity with the systems so as to enable us to effectively train police officers; and to establish certain bounds and limitations on the capabilities of the systems. A total of 19 engineering field tests was conducted with the devices:

Test 1 - Effect of Ambient Lighting on Photographic Capability
Test 2 - Effect of Range on Photographic Capability
Test 3 - Effect of Shadowing and Glare
Test 4 - Night Photography
Test 5 - Effect of Vehicle Speed on Photography and Accuracy of Speed Readings
Test 6 - Effect of Rain
Test 7 - Effect of Range on Radar Detection
Test 8 - Cosine Angle Effect
Test 9 - Effect of Traffic Density
Test 10 - Effect of Vehicle Type

Test 11 - Truvelo Detection Capability
Test 12 - Motorist Detectability of Across-the-Road Radar
Test 13 - Effect of Lane Change Maneuvers
Test 14 - Effect of Braking
Test 15 - Effect of Jammers on Radar Detection
Test 16 - Effect of Citizen Band Radio Transmission Interference
Test 17 - Effect of 161 Kv High Tension Line Interference
Test 18 - Effects of Different Lenses and Projection Systems
Test 19 - Effects of Using Color Film on Readability of License Plates

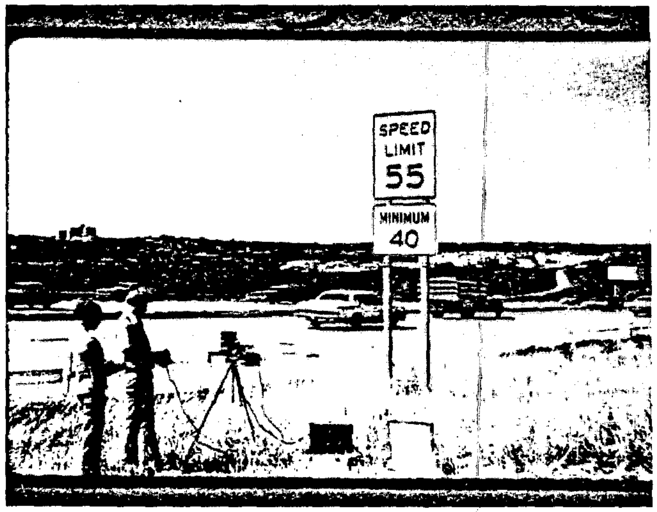
Some of the above tests took place in actual traffic, as illustrated in Figure 19a, while others were conducted under controlled situations in large, empty parking lots, as illustrated in Figures 19b and 19c, or on an unopened portion of an interstate highway. For tests conducted under controlled speed conditions, we used a test vehicle fitted with a Track-Test fifth-wheel assembly with an electronic digital speed readout capability accurate to within 1/2 mph from 0 to 100 mph. Both Missouri (MO) and Kansas (KS) license plates were employed in the various tests.

Several problems were encountered with the devices during the engineering field tests.

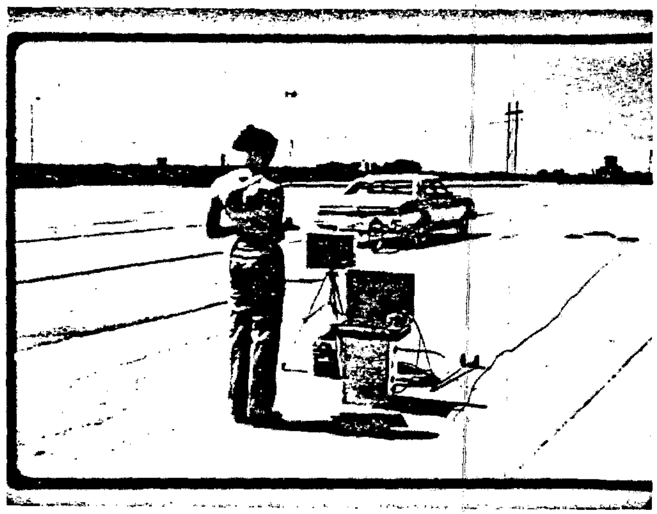
The Scott radar subsystem of the Gatso system developed an intermittent problem relating to its direction sensing abilities. The problem was similar to, but not as extensive as, an earlier problem found with the device during its acceptance testing. The James Scott Company was contacted for instructions or advice on the repair of the unit. At the manufacturer's suggestion, some of the test results along with the original direction sensing Doppler signal amplifier (DSDSA) printed circuit board were mailed to James Scott, Ltd. in Scotland. The repaired DSDSA printed circuit board, information regarding the cause of the failure and suggested repairs to alleviate the direction sensing problems were not received until after the Gatso device was undergoing law enforcement evaluation. This delay caused only a small loss in the engineering field test data.

An unexplainable, but brief, problem was also found with the SFIM radar subsystem of the Traffipax system during the engineering field tests. Several times during one of the tests the unit failed to acknowledge the presence of any vehicle in the radar beam. This problem corrected itself in the field and did not reoccur.

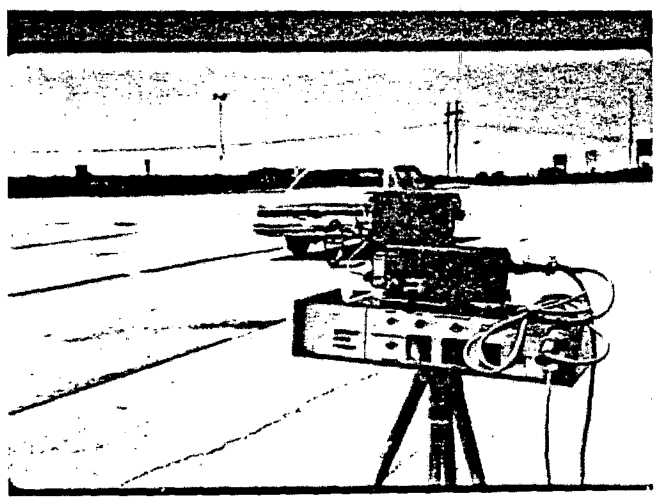
Early in the engineering field tests the Truvelo measuring instrument failed to respond to a test command. (The unit would not display the correct integers during a calibration check.) Shortly thereafter, the measuring instrument failed to process signals from the roadway sensors. At the instruction of the manufacturer, the measuring instrument was shipped to South Africa for repair under warranty. The unit was received back in Kansas City after a 3- to 4-week delay, checked out, and found to be operating properly. Several of the Truvelo engineering tests could not be completed because of the measuring instrument failure and the time schedule for the tests. However, many of the Truvelo photographic tests were conducted by manually triggering the camera subsystem. The assessment of the device's road cable detection system was postponed until after the measuring instrument was repaired.



a. Field Testing of Gatso.



b. Field testing of Truvelo.



c. Field Testing of Gatso.

FIGURE 19. ENGINEERING FIELD TEST ENVIRONMENTS.

A summary of the engineering field tests and their associated results are presented in Table 1 while the details are given in Appendix A. The quantities measured during each test are indicated along with the major findings for each of the four devices. For instance, Test No. 1 involved determining the effects of ambient lighting on the photographic capability of the devices. A clean Missouri license plate was used during the test to determine the minimum light level required for complete readability of the license plate number from the photographic film. The minimum light level is indicated by the aperture or f-stop setting at 1/30 sec shutter speed with ASA 400 film. The major results given for this test show that the flash of the Multanova should be activated whenever the ambient light level is lower than that corresponding to an f-stop of f8. The Gatso and Traffipax cameras can operate in lower light levels (f4) before flash is required. Other major findings from the various tests are enumerated below.

* Of the four devices, the Multanova photographic system provided the greatest distance range for readibility of the license plate numbers under daylight conditions. The Truvelo had the shortest photographic range.

* Shadowing of the license plate was not a problem for the four devices. However, glare when the sun was at low elevation angles greatly degraded readibility of the license plate numbers for all four devices, but only under a specific orientation condition. That condition was when the angle of sunlight reflection coincided with the aiming angle of the camera relative to the direction of traffic flow.

* Night time lighting conditions reduced the distance range for license plate readibility over day light conditions for three of the four devices. The Truvelo had the shortest photographic range of the four devices. The other devices had comparable night time photographic ranges, with the Multanova and Traffipax having slightly longer ranges for certain license plate designs.

* The effect of vehicle speed on the readability of the license plate numbers was the same for all four devices. The license plate numbers were readable for vehicles traveling as fast as 60 mph in the near lane (lane 1), but none were readable on vehicles traveling in the third (far) lane because of a combination of the long distance from the camera and the vehicle motion.

* The accuracy of the speed readings varied between the devices; and for each device, accuracy varied with the speed of the vehicle. The Gatso was the least accurate, overestimating the vehicle speed with a mean error of between 1.2 and 2.75 mph. These errors include the possibility of small misalignments of the devices.

TABLE 1.-SUMMARY OF ENGINEERING FIELD TESTS AND ASSOCIATED MAJOR RESULTS

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
1. Effect of Ambient Lighting on Photographic Capability (using MO license plate)	Minimum Light Level[a]	f4	f8	f4	f5.6
2. Effect of Range on Photographic Capability (using MO license plate)	Maximum Readable Range[b] (feet)	135	150[c]	90	60
3. Effect of Shadowing and Glare (using MO & KS license plates)	Angles (in degrees from true north) License Plates Unreadable				
A. Sun overhead					
Shadow		None	None	None	None
Glare		None	None	None	None
B. Sun at mid-elevation					
Shadow		None	None	None	None
Glare		None	None	None	None
C. Sun at low elevation					
Shadow		None	None	None	None
Glare[d]		22.5° (KS)	22.5° (both plates)	22.5° (both plates)	22.5° (both plates)

TABLE 1 (continued)

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
4. Night Photography (using MO and KS license plates)	Maximum Readable Range (feet)	90 (both plates)	90 (KS) 90 to 135 (MO)	90 (MO) 150 (KS)[e]	60 (both plates)[e]
5. Effect of Vehicle Speed on Photography and Accuracy of Speed Readings (using MO license plate)	Maximum Readable Speed (mph):				
	Lane 1	60[c]	60[c]	60[c]	60[c]
	Lane 3	(blurred)[f]	(blurred)[f]	(blurred)[f]	(blurred)[f]
	Accuracy[g] of Speed Reading for:				
	40 mph	+1.75(2.06)	0.00(1.27)	-0.14(0.69)	No Data
	50 mph	+1.20(1.10)	0.00(1.10)	-0.50(1.05)	No Data
	60 mph	+2.75(0.50)	+0.33(0.82)	-0.67(1.21)	No Data
6. Effect of Rain	Number of Readable License Plates[h]				
	Lane 1	2 out of 2	4 out of 4	4 out of 7	2 out of 7
	Lane 2	2 out of 5	6 out of 10	2 out of 16	1 out of 20
7. Effect of Range on Radar Detection	Maximum Lateral Position (feet) for:				
	100% Detection	55	40 (short range) > 55[c] (medium range) > 60[c] (long range)	35 (short range) 45 (long range)	Not Applicable
	50% Detection	> 60	42 to 43 (short range) > 55[c] (medium range) > 60[c] (long range)	37 to 38 (short range) 50 (long range)	Not Applicable

TABLE 1 (continued)

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
8. Cosine Angle Effect	Speed[i] Measurement Error				
	22° Angle	3.5% High	0.2% High	0.7% Low	Not Applicable
	30° Angle	4.4% Low	8.3% Low	7.1% Low	Not Applicable
	Effect of 8° alignment error	-7.9%	-8.5%	-6.4%	
9. Effect of Traffic Density	Maximum % Vehicles Detected at Low Vehicle Count Per Hour (VPH) Flow Rate	100%	100%	96%	No Data
	% Rate of Change of % Vehicles Detected With Increasing Flow Rates (per 1,000 VPH)	15% Reduction	18% Reduction	19% Reduction	No Data
	Maximum % Violations Detected at Low Vehicle Flow Rates (VPH)	86%	100%	95%	No Data
	% Rate of Change of % Vehicle Violations Detected with Increasing Flow Rates (per 1,000 VPH)	13% Reduction	18% Reduction	19% Reduction	No Data

TABLE 1 (continued)

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
10. Effect of Vehicle Type	Manual and Device Counts by Vehicle Type				
	Association Between Missed Detections and Vehicle Type for:				
	Lane 1	Not Significant	Short Range-Not Significant Long Range-Significant (missed more trucks than passenger vehicles)	Not Significant	No Data
	Lane 2	Not Significant	Short Range-Not Significant Long Range-Significant (missed more trucks than passenger vehicles)	Not Significant	No Data
	Association Between Missed Detections and Lane Number for:				
	Trucks	Not Significant	Short Range-Not Significant Long Range-Significant (missed more trucks in Lane 1 than in Lane 2)	Not Significant	No Data
	Passenger Vehicles	Not Significant	Short Range-Not Significant Long Range-Not Significant	Not Significant	No Data

TABLE 1 (continued)

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
10. Effect of Vehicle Type (continued)	Association Between Missed Violations and Vehicle Type for:				
	Lane 1	Not Significant	Short Range-Not Significant Long Range-Significant (missed more trucks than passenger vehicles)	Not Significant	No Data
	Lane 2	Not Significant	Short Range-Not Significant Long Range-Significant (missed more trucks than passenger vehicles)	Not Significant	No Data
	Association Between Missed Violations and Lane Number for:				
	Trucks	Not Significant	Short Range-Not Significant Long Range-Significant (missed more trucks in Lane 1 than in Lane 2)	Not Significant	No Data
	Passenger Vehicles	Not Significant	Short Range-Not Significant Long Range-Not Significant	Not Significant	No Data

TABLE 1 (continued)

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
11. Truvelo Detection Capabilty	Number of Detections	Not Applicable	Not Applicable	Not Applicable	995 out of 1,002 (99.3%)
12. Motorist Detectability of the Multanova with a Fuzzbuster Radar Detector	Relative Signal Strength Detected by Fuzzbuster	Not Applicable	Beam Totally Undetectable Very Short Distance Upstream of Transmitter. Maximum Power Concentrated Along Theoretical Beam	Not Applicable	Not Applicable
13. Effect of Lane-Change Maneuvers	Number of Detections	8 out of 8	6 out of 6	6 out of 6	No Data
	Speed Reading Error for Lane-Change From:				
	Left to Right (towards device)	3.0% Low	10.1% Low	6.1% Low	No Data
	Right to Left (away from device)	5.2% High	1.0% High	3.8% High	No Data
14. Effect of Braking	Number of Detections	6 out of 6	3 out of 7[j]	6 out of 6	No Data
15. Effect of Jammers on Radar Detection	False Readings	None	None	None	Not Applicable
16. Effect of Citizen Band Radio Transmission Interference	Observations of Effects	No Effects	No Effects in Lane 1. 15% Reduction in Detection in Lane 2	No Effects	No Data

TABLE 1 (continued)

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
17. Effects of 161 Kv High Tension Line Interference[k]	Manual and Device Counts by Vehicle Type				
	Association Between Missed Detections and High Tension Line Interference for:				
	Trucks in Lane 1	Not Significant	Not Significant	Not Significant	No Data
	Trucks in Lane 2	Not Significant	Not Significant	Not Significant	No Data
	Passenger Vehicles in Lane 1	Not Significant	Not Significant	Not Significant	No Data
	Passenger Vehicles in Lane 2	Significant-Missed More Passenger Vehicles (12.4%) in Presence of High Tension Lines	Not Significant	Not Significant	No Data
	Association Between Missed Violations and High Tension Line Interference for:				
	Trucks in Lane 1	No Data	Not Significant	Not Significant	No Data
	Trucks in Lane 2	No Data	Not Significant	Not Significant	No Data
	Passenger Vehicles in Lane 1	No Data	Not Significant	Not Significant	No Data
	Passenger Vehicles in Lane 2	No Data	Not Significant	Not Significant	No Data

TABLE 1 (concluded)

Test Description	Quantities Measured	Gatso Mini Radar	Multanova	Traffipax	Truvelo
18. Effects of Different Lenses and Projection Systems	Percentage License Plates Totally Readable in:				

	Length of Lens[1] and Projection System								
	75 mm Lens			135 mm Lens			200 mm Lens		
	150 Watt Filmstrip Projector[m]	500 Watt Filmstrip Projector	500 Watt Microfilm Reader	150 Watt Filmstrip Projector[m]	500 Watt Filmstrip Projector	500 Watt Microfilm Reader	150 Watt Filmstrip Projector[m]	500 Watt Filmstrip Projector	500 Watt Microfilm Reader
Lane 1	67%	82%	85%	93%	93%	93%	100%	100%	100%
Lane 2	31%	58%	77%	84%	84%	84%	No Data	No Data	No Data

Test Description	Quantities Measured
19. Effects of Using Color Film on Readability of License Plates	Percentage License Plates Totally Readable in:

	Length of Lens[1] and Projection System					
	75 mm Lens			135 mm Lens[n]		
	150 Watt Filmstrip Projector[m]	500 Watt Filmstrip Projector	500 Watt Microfilm Reader	150 Watt Filmstrip Projector[m]	500 Watt Filmstrip Projector	500 Watt Microfilm Reader
Lane 2	25%	61%	71%	7%	52%	82%

FOOTNOTES FOR TABLE 1

[a] Minimum light level is indicated by the aperture (f-stop) setting at 1/30 sec. shutter speed with ASA 400 film.

[b] Greater range than indicated might be possible for some license plate numbers.

[c] Maximum value tested.

[d] License plate glare occurred only when sunlight was reflected directly from the license plate into the camera, i.e., when the angle of sunlight reflection coincided with the aiming angle of the camera relative to the direction of traffic flow.

[e] The wheat stalk in the background of the Kansas license plates impaired the readability of the county designator and the alphabetical code of the license number; the numerical code values were readable.

[f] The license plate was not readable at speeds as low as 40 mph, due to motion blur and marginally long range.

[g] The mean and standard deviation (in parenthesis) of the error in mph were determined relative to the speed measurement made using a U.S. manufactured radar (Digitar).

[h] A combination of underexposure (due to lack of sufficient light) and spray contributed to the unreadability of the plates. Most of the photographs were underexposed regardless of the use of the flash. Spray obliterated some of the plates located within the spray pattern behind the car. Rain drops on the windshield of the Traffipax car also caused degradation of the vehicle image. Splash was not found to be a problem.

[i] The speed measurement error is referenced to a fifth wheel speed measurement. The calculated error for an 8 degree misalignment is 6.6% decrease in speed indicated by the device.

[j] The Multanova device became confussed during 4 of the 7 detections. In these 4 cases the vehicle's detected speed was only briefly displayed. A hard copy record of the speed could be obtained but it is believed that a photograph would not have been taken if the camera had been used.

[k] During Test No. 17, both the Multanova and Traffipax devices were operated on the short range selections.

[l] All four devices tested were supplied with a standard 75 mm lens. Consequently the results presented apply equally to each device.

[m] The 150 watt projector is the same as provided to the law enforcement agencies in their preliminary evaluation of the devices.

[n] The color film used with the 135 mm lens was improperly exposed (under exposed). This produced readability problems and placed in question some of the percentage data for the 135 mm lens.

* The effects of rain on the readability of license plate numbers varied between devices and, for a given device, between lanes. Based on very small samples, the percentage of plates readable in lane 2 was less than the percentage of plates readable in lane 1. Also, rain presented more of an identification problem for the Traffipax and Truvelo than for the other two, with the Truvelo being the most affected.

* The maximum lateral detectable range for Multanova and Traffipax increased as their range selection was increased (from short to long range). The range for 100% detection (at maximum range setting) varied slightly between the devices. Of the three devices using radar, the Multanova had the greatest maximum lateral range (over 60 ft) for 100% detection.

* The speed measurement error of the three radar devices due to the cosine effect was relatively small, except for the Gatso, when set at the proper alignment angle. The three devices, when purposely missaligned by 8 degrees, correctly exhibited a reduction in indicated speed. The reduction was close to the theoretical value of 6.6%.

* The Gatso and Multanova successfully detected all vehicles under low traffic flow rate conditions (low vehicle counts per hour). The Traffipax missed detecting only 4% of the vehicles at low flow rates. As the flow rate increased the three radar devices missed from 15 to 19% of the vehicles per 1,000 vehicles per hour.

* The Multanova successfully detected all violating vehicles under low traffic flow rate conditions. The Traffipax missed only 5% while the Gatso missed 14% of the violating vehicles at low flow rates. At higher flow rates the three radar devices missed between 13 and 19% of the violators per 1,000 vehicles per hour.

* No significant relationship was found for the three radar devices between missed vehicle detections and vehicle types or classifications for either lane 1 or 2. The only exception to this occurred when the Multanova was operated at the long-range setting. At this setting, the device missed more trucks than passenger vehicles in both lanes. Moreover, it missed more trucks in lane 1 than in lane 2.

* The effect of vehicle type on missed violations was the same as stated above for missed vehicle detections.

* The Truvelo was able to detect almost all (99.3%) of the vehicles passing over its detection cables for a wide range of traffic flow conditions.

* The electromagnetic radiation emitted by the Gatso and Traffipax with frequencies of 13.45 and 9.41 GHz, respectively, could not be detected by a standard Fuzzbuster radar detector

designed to be sensitive to the X-band (10.525 GHz). The X-band beam emitted by the Multanova was detected by the Fuzzbuster, but only under specific conditions. The Multanova's radiation pattern was totally undetectable alongside or to the rear of the device. The maximum power of the radiation was concentrated along the theoretical beam. Therefore, the beam generally would not be detected by receding traffic unless the Fuzzbuster was positioned facing the rear of the vehicle instead of its normal, forward facing position. The beam could be detected by approaching traffic, but the Multanova would not be monitoring this traffic.

* Vehicle detection by the three radar devices could not be avoided by severe lane change maneuvers as the vehicle enters the radar beam. The maneuvers did have an influence on the radar speed reading. Lower speed readings were observed when lane changes were made towards the device, and higher speed readings were observed when lane changes were made away from the device, in accordance with the cosine effect.

* Vehicle detection by the Gatso and Traffipax could not be avoided by severe braking maneuvers. The Multanova failed to positively identify slightly over half of the vehicles undergoing severe breaking maneuvers. The maneuvers produced speed readings that were substantially less than the initial vehicle speed, perhaps because the radar units "locked on" to the vehicle during the deceleration.

* No false speed readings were recorded by any of the three radar devices when tested against two radar jammers.

* Citizen band radio transmission near the Gatso and Traffipax did not interfere with the detection capability of these devices. The CB transmission did interfere with the ability of the Multanova device to detect vehicles in lane 2 but not in lane 1. A 15% reduction in vehicle detections was noted for lane 2.

* Operating the Multanova and Traffipax near a 161 Kv high tension line had no significant effect upon the number of missed vehicle detections and missed speed violations observed for the two devices. These results were valid for all vehicle type-lane number combinations investigated. A significant interference effect, albeit limited, was observed for the operation of the Gatso. Significantly more passenger vehicles (12.4%) were missed (at a 95% confidence level) in lane 2 when the device was operated in the presence of the high tension line.

* The use of longer camera lens (longer than the standard 75 mm supplied with the device cameras) greatly enhances the readability of the vehicle license plates from the photographic negatives. The improvement in readability of license plates photographed with 135 mm and 200 mm lenses over those

taken with the 75 mm lens was greater for lane 2 than for lane 1. Also, the incremental improvement between a 75 mm lens and a 135 mm lens was greater than the incremental improvement between the 135 mm and 200 mm lens.

* The use of a higher wattage and higher quality projection system increased the readability of the license plates photographed in both lanes with a 75 mm lens.

* The need for precise exposure settings adversely affects the desirability of using color film in conjunction with a lens longer than 75 mm.

* When a 75 mm lens was used, no discernible improvement in readability was noted when color film was used in place of black and white film.

* The use of color film, however, enhances the positive identification of the state origin of the license plate and improves the readability of some license plates with poor color contrast.

It must be emphasized that many of the limitations reviewed above relative to license plate readability could be alleviated through license plate redesign. In most of the world the vehicle license plates are much longer than in the U.S., and have large, high contrast letters and numbers, as illustrated in many of the photographs in Chapter III.

VII. PRELIMINARY LAW ENFORCEMENT AGENCY EXPERIENCE

Preliminary law enforcement field tests of the four ASE devices were conducted by units of the Maryland, Illinois, and New Jersey State Police. The objectives of these tests were to:

- Assess the police training requirements for the use of the devices;
- Identify potential problem(s) associated with the use of the units; and
- Evaluate the general acceptability of the devices by law enforcement personnel.

This chapter contains two parts. The first describes the preparation for, and conduct of the preliminary law enforcement testing of the four selected ASE devices. Included in this part are discussions of the solicitation of cooperation from the state police agencies, the preparation of instructional/operational materials for training purposes, the development of operational/procedural test plans, and the training of the law enforcement personnel in the use of the devices. A brief summary of the testing activities is also given.

The second part presents a summary of the state police agencies' experiences, including problems encountered during the testing and their opinions of the ASE devices tested.

A. Preparation for and Conduct of Preliminary Law Enforcement Testing of ASE Devices

During the latter stages of the engineering field tests, NHTSA contacted several state police agencies regarding their interest and possible cooperation in the operational testing of the four selected ASE devices. The state police in Maryland, Illinois, and New Jersey responded to the initial inquiry with expressed interest. MRI project personnel made a presentation to the command staff of each agency briefly describing the project, the plans for the field evaluation, what MRI/NHTSA would provide the state, and the need for the state's cooperation. Personnel from NHTSA participated in the presentation made to the Maryland and New Jersey State Police. Cooperation was extended by the superintendents of all three agencies.

Training manuals and materials were developed for each device. The documents were developed from the manufacturer-provided manuals and the results of our engineering field tests. The quality of the manuals provided by the manufacturers was uneven; some were quite good and very thorough while others were somewhat rough translations or incomplete. The user's manuals developed averaged 55 pages in length and contained sections pertaining to:

- Introduction to the system;
- System components;
- Operating instructions;
- Operation without camera;
- Disassembly and storage;
- Film processing and analysis;
- Trouble shooting, including special hints and precautions;
- Routine maintenance; and
- Technical specifications.

The manuals contained numerous figures, especially of the devices' components. Some of the figures were extracted from the manufacturer's manuals, while most were developed using in-house resources. Liberal use of labeling was used in the figures.

The portions of the manuals dealing with operating and disassembly instructions were written in a step-by-step format. The manual sections and the operating and disassembly statements were indexed using the military (decimal) numbering system.

Each state police agency was given an opportunity to test as many of the four devices as possible. All three agencies agreed to test the Gatso, Multanova, and Traffipax devices; the Maryland State Police was the only agency agreeing to test the Truvelo device.

Operational/procedural test plans were developed for each device. These plans included highway test site selection procedures, recommended tests to be conducted, test procedures, data needs, and agency reporting requirements. The plans were modified as necessary to accommodate cooperating agencies' limitations.

General site selection procedures were described in the user's manual developed for each device. The selection of the specific highway sites for all but the Multanova was left to each agency. A requirement was made, however, that the testing be conducted on a variety of highway types with speed limits of 55 mph.

The selection of Multanova test sites within each agency jurisdiction was accomplished in a formal manner. Two sites were selected on interstate facilities in each jurisdiction by MRI personnel with the assistance of the respective state police. These site selections were made during a training session for one of the other devices.

Special arrangements were made in each state to have a concrete pad constructed at each of the two Multanova site locations. The pads were used to support and steady the Multanova roadside cabinets. The details of the placement and construction of the pads were specified by MRI with the assistance of Department of Transportation (DOT) officials in each of the three states. The construction of the pads was accomplished by either a private contractor under supervision of the state police or by state DOT maintenance personnel.

Between 40 and 50 tests of each device were recommended to be conducted by each jurisdiction. The recommended tests incorporated a variety of highway types (interstate, multi-lane divided and undivided; and 2-lane highways) for all but the Multanova and a variety of environmental conditions (weather, lighting, and sun positions). No formal experimental design was established for the testing. Some of the test conditions were replicated to provide an opportunity for several troopers to test the equipment under similar conditions. Many of the recommended test conditions were also included in the engineering tests. A table of the recommended tests for each device was given to the command staff for assignment purposes.

The test procedures, data needs, and agency reporting requirements were distributed as a supplement to the user's manual during the training sessions. These items mainly pertained to tests conducted with the devices using their photographic capability. Qualitative comments were also solicited from the troopers on the operation of the devices during non-photographic testing. The test procedures contained instructions on setting up the data chamber with a data code that would later be used to help properly identify the exposed film during its analysis.

A data log sheet was developed to assist the troopers and data film reviewers in the consistent recording of data during their evaluation of the ASE devices. The data log sheet used is shown in Figure 20. The form consists of two basic parts, separated by a heavy line about a quarter of the way down the page.

The top part of the form was filled out in the field by the trooper operating the detection device. This portion contains such items as: the device being evaluated; the officer's rank and name (or number); the date and time of the test; the location of the test; the number of photographic frames exposed, the device's speed and range settings; the environmental conditions at the time of the test; and finally, an identifier data code. The first three digits of this code describe the route number of the test location while the fourth, fifth, and sixth digits describe the light conditions, weather, and sun position, respectively, at the time of the test. For example, a data code of 127112 would indicate the test was conducted on Highway 127 during daylight when the sky was clear and the sun was overhead. The data code for each test condition was placed in the data chamber of the photographic system before any tests were conducted with the devices using their photographic capability.

The bottom three-fourths of the data log sheet was for recording data taken from the film exposed during the device field tests. This part of the form contains provisions for recording, by frame number, the following information: the license plate number of the detected vehicle; the license plate year; the time of day the picture was taken; the vehicle's speed; whether or not the offending vehicle could be picked out from among other vehicles in the frame; the lane number of the offending vehicle (counting lane 1 as the shoulder lane); the offending vehicle type; the state of the license plate; the readability of the license plate; if unreadable, the reason(s) why; whether or not the vehicle owner could be identified; and if not, the reason why. The film reviewer was encouraged to record on the back of the log sheet any comments regarding the review of a particular frame.

MIDWEST RESEARCH INSTITUTE - STATE POLICE DATA LOG

DETECTION DEVICE: __ TRAFFIPAX __ GATSO __ TRUVELO __ AMDAR __ MULTANOVA

Number of Frames Exposed ______

Device Speed Setting ______ mph/km/h

Device Range Setting: __ Short (I) __ Medium __ Long (II) __ Not Applicable

____
Officer's Rank and Name or Number

Date of Test ______ (Day/Month/Year)

Time Data Collection Began ______ MIL Time Data Collection Ended ______ MIL

LOCATION OF TEST

Route No. __ __ __

County ______

State ______

No. of Lanes Monitored (One Way) ______

Speed Limit ______ mph

ROAD TYPE

__ Controlled Access (Interstate)

__ Multi-Lane, Divided

__ Multi-Lane, Undivided

__ Two lane

ROAD SURFACE TYPE

__ Concrete

__ Blacktop

__ Other

______ (Specify)

LIGHT CONDITION

1 __ Daylight

2 __ Dawn-Dusk

3 __ Darkness No Streetlight

4 __ Darkness Streetlight on target

WEATHER

1 __ Clear

2 __ Cloudy

3 __ Raining

4 __ Snowing

5 __ Fog

6 __ Other

______ (Specify)

SUN POSITION

1 __ Facing Camera

2 __ Overhead

3 __ Behind Camera

4 __ Not Applicable (Cloudy/Night)

DATA CODE: Route No. __ __ __ Light Condition ____ Weather ____ Sun Position ____

License Plate Number	License Plate Year	Frame No.	Recorded Time	Vehicle Speed	Offending Vehicle Obvious Yes	Offending Vehicle Obvious No	Lane No. of Offending Vehicle*	Type of Vehicle (See Code)	State of License Plate In	State of License Plate Out	State of License Plate Unk	License Plate Readable Yes	License Plate Readable Part	License Plate Readable No	Reason Plate Unreadable (See Code)	Vehicle Owner Identified Yes	Vehicle Owner Identified No	Reason Owner Not Identified (See Code)
		1																
		2																
		3																
		4																
		5																
		6																
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		36																
TOTALS																		

* Code the Shoulder Lane as Lane 1

VEHICLE TYPE CODE

1 Truck Tractor with Trailer
2 Single Unit Truck
3 Bus
4 Recreational Vehicle
5 Pickup, Panel Truck or Van
6 Car
7 Pickup, Panel Truck or Van with Trailer
8 Motorcycle

REASON PLATE PARTIALLY/TOTALLY UNREADABLE

1 Blurred
2 Glare
3 Overexposure
4 Underexposure
5 Blocked View
6 Spray
7 Rain Drops
8 No Plate
9 Plate Not in Frame
10 Other ______ (describe)

REASON OWNER NOT IDENTIFIED

1 Plate Problem
2 Out of State Owner
3 No Registration Record for In-State License
4 Other ______ (describe)

FIGURE 20. STATE POLICE DATA LOG.

A separate log sheet was to be filled out for each roll of film exposed.

A training session was held each time a device was delivered to one of the agencies for testing. The training sessions were attended by troopers assigned to the particular device testing, a supervising sergeant, an individual assigned to review the data film, and, on some occasions, various personnel from the command staff. Each training session lasted approximately 1 day and concentrated on field operations rather than classroom work and theory. A brief portion of each session was spent in the classroom familiarizing the personnel with the individual components and operation of the device. This was followed by a demonstration of the device's operation in an actual traffic environment. The trooper training was concluded with a review of the data reporting requirements including a discussion of a data log sheet. The troopers were encouraged to turn in to the designated personnel the exposed film and associated data log sheets after a particular field test had been completed. Also, the officers were requested to attach to the appropriate data log sheets any written remarks regarding the operation of the detection device. It was recommended to the supervising sergeant that the film should be processed as soon as possible and then turned over, along with the data log sheet, to the personnel responsible for analyzing the film.

Finally, the selection of the training manual dealing with film processing and analysis was briefly reviewed with the individual assigned to review and analyze the exposed film using a project supplied 150 watt film strip projector. During the Gatso and Multanova training, particular emphasis was given to the design features of these devices that aid in the identification of the offending vehicle during the film analysis. Any film review problems encountered by the assigned personnel were discussed when necessary at the end of the training session.

A plan for rotating the devices among the three agencies was developed with their cooperation. Each agency was provided the opportunity to test each assigned device over a period of 4 to 6 weeks. In some cases, this period was extended to accommodate delays in testing resulting from staff assignments, weather problems, etc.

The devices and their support equipment were transported from agency to agency by MRI project personnel. The Traffipax device was transported installed in its assigned vehicle - a government-supplied, 2-door intermediate size passenger vehicle. The Multanova and its two roadside cabinets were transported in a government-supplied van and a towed trailer. The other two devices were shipped by air and/or ground transportation using especially made wooden crates.

The preliminary law enforcement field tests were conducted during the period of December 1980 through June 1982. The deployment strategies using the photographic capability of the devices were implemented to the point of processing and viewing the film, identifying the license plate numbers, and determining procedures necessary for retrieval of vehicle owner identification. Throughout the preliminary law enforcement testing no contact was made with the speeding violators detected. A brief summary of the testing activities by state agency is given below.

* <u>Maryland State Police</u>

The testing in Maryland was confined to the Baltimore metropolitan area. Six uniformed troopers from that area were assigned to the testing and operated in teams of two. One field sergeant was selected to perform day-to-day supervision and was also given the responsibility to read the film, record data extracted from the film review, and to write the draft evaluation reports. The film was processed by the Crime Laboratory Division.

* <u>Illinois State Police</u>

The testing activities in Illinois varied, depending upon the particular device being evaluated. Half of the Traffipax testing was conducted by five troopers in an area around Springfield, the other half of the testing was conducted by five troopers in an area near East St. Louis. In each area the troopers worked in teams of two so they could assist one another. The Multanova was tested at two locations on I-55 in the Springfield area. Five troopers, including one involved with the Traffipax testing, were assigned to Multanova testing. The troopers worked in teams of two until they became familiar with the device, at which time they worked singularly. The Gatso testing was assigned to only one trooper who worked in the Springfield area in an unmarked patrol car. This trooper was also involved with the Multanova testing, but not the Traffipax. Throughout the testing, the troopers wore civilian clothes.

A sergeant from the Staff Services Command in Springfield was assigned to perform day-to-day supervision and to serve as a liaison between the State Police and MRI. The sergeant also was responsible for assembling the written evaluation comments from the participating troopers.

The film exposed during the testing was processed by the State Police Support Services in each testing area. The processed film was then forwarded to an individual in the administrative section of the State Police Headquarters in Springfield for review and data extraction.

* <u>New Jersey State Police</u>

The testing activities in New Jersey were confined to an area around Morristown, New Jersey. Four uniformed troopers plus one uniformed sergeant from a tactical patrol unit of the Troop B Headquarters in Morristown were assigned to the testing. All five were involved with the Gatso testing; but only one of the four troopers was involved with the Traffipax and Multanova testing because of staffing problems. A field sergeant from the Traffic Bureau at the State Police Headquarters in West Trenton was selected to supervise the field tests and was also given the responsibility to read the film, record data extracted from the film review, and assemble the evaluation comments from the participating trooper(s).

B. Summary of Preliminary Law Enforcement Agency Experience

Evaluation reports documenting the state police agencies' experiences with the ASE devices and the results of the film analyses were submitted to MRI at the end of the preliminary law enforcement field tests. These documents varied from simple letter type reports to more extensive bound reports. In person debriefings were conducted with personnel in two of the police agencies to obtain their experiences and opinions on specific elements related to the ASE devices tested. Information on the experiences and opinions of personnel in the third agency was received in a report. The information from the evaluation reports and debriefings was pooled and is summarized in this section by device, where possible.

Table 2 presents a summary of the comments received from the troopers involved in the preliminary law enforcement tests. The comments are divided into nine major categories covering: training, device set up, device operations, device tear down, traffic flow, general impressions about the equipment, general impressions about the deployment strategy used, how the device compares with the others tested, and overall comments. Some of the major categories were further subdivided. The major findings in Table 2 are enumerated below.

* The troopers felt the training manuals developed for all the devices were very useful and easy to follow. They thought the 1-day combined classroom and field training was sufficient for the preliminary tests. However, more extensive training would be needed for all the devices except the Traffipax if used for enforcement.

* One person could set up either the Gatso, Multanova or Traffipax in 10 to 15 min. However, it took two people 15 to 20 min to set up the Truvelo.

* Only minor prolems, particularly with connection plugs or cables, were experienced during the set up of the Gatso, Multanova or Traffipax devices. The set up of the Truvelo presented some traffic safety problems for the troopers. The set up had to be performed by at least two troopers and they had to close the lane to install the roadway cables on heavily traveled roads.

* The suggested improvements for set up pertained mainly to simplifying the cable connection operations or modifying the lengths of connector cables.

* Generally, the troopers had something good to say about the operation of each device. Most favorable comments were noted for the Multanova.

* Several operational problems were encountered with all but the Multanova device which presented no particular problem of a persistent nature.

TABLE 2.-SUMMARY OF COMMENTS FROM TROOPERS INVOLVED IN PRELIMINARY LAW ENFORCEMENT TESTS

Item	Gatso Mini Radar	Multanova	Traffipax	Truvelo
1. Training				
A. Manuals	Very useful, excellent training aid.	Good, provided all the operational and troubleshooting information needed.	Good, easy to follow.	Excellent training aid.
B. Practice	Sufficient.	Adequate, but could have used more.	Adequate.	Sufficient.
C. Length of time provided	One day combined classroom and field training sufficient for preliminary tests.	Same as for Gatso.	Same as for Gatso.	Same as for Gatso.
D. Suggested improvements	More extensive training would be needed if used device for enforcement.	More detailed manual and extensive training would be needed if used device for enforcement.	None.	More extensive training would be needed if used device for enforcement.
2. Device Set Up				
A. Time required	10 to 15 minutes for one person; easy to set up with instructions provided in manual.	10 to 15 minutes for one person with some practice.	10 to 15 minutes for one person; easy to set up with instructions provided in manual.	15 to 20 minutes for two people.
B. Problems encountered	Connector plugs were difficult to use, especially in cold weather.	Roadside cabinets need more room inside to make cable connections more convenient. Also, the excess cable length made cabinet too cramped. Need two people to calibrate device. Some troopers could not get device to respond to the smaller tuning fork during calibration.	Hard to connect cables to bottom of radar antenna and to car. Had some minor problems in setting up and leveling antenna. Thought antenna was too big and awkward to handle.	Had to close lane to install roadway cables on heavily traveled road. Particularly dangerous to install roadway cables at night on heavily traveled roads. Set up had to be performed by at least two troopers.
C. Suggested improvements	Color code the connector cables; could use longer cable for the readout box.	Simplify cable connection operation; increase size of roadside cabinet; shorten cables; improve calibration procedure; and use 110 VAC instead of batteries to power device.	Use different type of connectors for cables connecting antenna to car. Cable connector location on antenna should be moved to more convient location.	None.

TABLE 2 (continued)

Item	Gatso Mini Radar	Multanova	Traffipax	Truvelo
3. Device Operations				
A. Things liked	Effective tool for speed enforcement, especially if used with a stop team; portability was good but mobility was limited.	Troopers liked the preset cabinets and aiming guides. These helped eliminate human error during set up and contributed to relatively trouble free operations. Troopers feel device would save lot of manpower in enforcing speed limit on interstate system.	Mixed feelings among troopers. Some thought the device was an effective tool for speed enforcement; others liked the device because they could work in the car monitoring traffic and changing film; and others thought the device was a step backward in radar detection.	Accuracy of device plus selectivity in its identification of speeders.
B. Problems encountered	Sometimes detected opposing traffic and sometimes would not detect receeding traffic; pictures tended to be of poor quality, possibly because of problems with automatic exposure control.	Sometimes missed very high speed vehicles in nearest lane. Otherwise, no signigicant problems encountered.	Cramped working conditions when two officers were in car. Troopers thought camera mounting on dashboard and control unit mounted under dashboard were potential injury producing hazzards to occupants.	Troopers did not like parking close to the roadway to protect the device from being struck by passing vehicles. On one occasion the turbulent wake from a tractor-trailor knocked down the tripod-mounted camera subsystem. Troopers felt the bulkiness of the equipment would restrict the mobility of any speed enforcement operations. Other problems encountered were associated with equipment malfunctions/breakdowns.
C. CB or police radio interference	CB or police radio transmission did not cause interference with speed detection.	No reported interference.	The flash and/or camera unit was triggered when a police radio mike, either in the Traffipax car or a patrol car alongside the Traffipax car, was keyed.	No reported occurrence of CB or police radio transmission causing interference with speed detection.
D. Malfunctions/ breakdowns	Film jammed in camera, especially in cold weather when temperature was at or below 10°F. Also, unit broke down on several occasions requiring laboratory repair.	Film jammed on few occasions resulting in blown fuses. Sometimes camera took single photograph of violating vehicle instead of the two expected.	Blew a lot of fuses - mainly in the camera. Calibration was not stable and drifted slightly within a test. Automatic exposure did not always work and had to be manually adjusted at times. Also, had some minor malfunctions of the mode switch.	Internal battery in measuring unit failed and could not be recharged; impedance converter failed and had to be replaced; flash cable shorted out and had to be repaired; and camera fuse shorted out several times.

TABLE 2 (continued)

Item	Gatso Mini Radar	Multanova	Traffipax	Truvelo
E. Weather problems	Could not use system in rain because it was not waterproof. Radar would not operate at temperatures at or below 15°F. Film became brittle and sprocket holes tore, resulting in film jamming when temperature was at or below 10°F.	No major weather problems reported. Some troopers suspect it might have problems with film becoming brittle and tearing in cold weather.	Front windshield fogged up during winter because could not use car's defrost or heat control while radar was operating. Also, troopers got cold in car when they were operating the radar.	During cold weather (tempera-around 20°F), road cables became very stiff and brittle. Outer protective insulation of road cables was shredded after 5-hours of exposure to heavy truck traffic during cold and wet weather. Film was brittle and broke on several occasions during cold weather.
F. Day/night operations	No basic problems, however, did not like setting unit outside of the vehicle and parking close to unit and roadway. Thought flash was very bright, but not a traffic hazard. Did not like using two power sources when using the flash.	No problems and no complaints from motorists when flash was used at night.	Needed flashlight at night to set up and load film. Troopers experienced some difficulty in aligning the radar antenna at night. Thought flash was very bright and might be a distraction hazard on two-lane roads. Some troopers saw brake lights come on in response to the use of the flash.	Troopers felt it was very dangerous working with the device at night on a heavily traveled road. The flash intensity did not appear to cause motorists any difficulty.
G. Suggested improvements	Make unit more compact and weatherproof. Also recommended camera be redesigned to use film cassets. Unit would be more functional if it had compact power source or operated from 12-volt outlet in car.	Have speed reading reset to zero after speed has been recorded. Also, would like device to shut down if camera malfunctioned. Would like cabinets designed larger and cables shortened.	Provide an auxiliary power source with the system so the car's heater and defroster can be used during radar operation. Speed limit settings should be variable and in mph units instead of metric.	Make unit more compact. A breakaway connection should be used between the roadway cables and impedance converter to prevent damage to the converter, input cable or measuring instrument if the roadway cables were ripped up. Camera should be designed with an automatic exposure control.
4. Device Tear Down				
A. Time required (normal/ emergency)	10 minutes for one person under normal conditions. 5 minutes for one person under emergency conditions.	10 minutes for one person under normal conditions. 1 minute for one person under emergency conditions.	5 to 10 minutes for one person under normal conditions. 2 to 3 minutes for one person under emergency conditions	No estimate of time required was available.

TABLE 2 (continued)

Item	Gatso Mini Radar	Multanova	Traffipax	Truvelo
B. Problems encountered	No basic problems. However, troopers felt it took too much time to tear down unit and properly store in carrying cases. They felt the tear down and set up time hindered their mobility to change locations, especially when areas were unproductive. Also, did not like dismanteling equipment in a hurry for fear of damaging it.	No basic problems other than cramped quarters inside roadside cabinets.	Had problems with accessibility to cable connectors on the radar antenna and on the bumper area of car.	Troopers felt that tear down (and set up) time was too long for economical speed enforcement operations. Had to close lane to remove roadway cables on heavily traveled roads. Tear down had to be performed by at least two troopers. Also, particularly dangerous to remove roadway cables at night on heavily traveled roads.
C. Suggested improvements	Make unit self-contained; and redesign unit to include fewer and shorter connecting cables.	Shorten cables and design roadside cabinet with more internal room.	Would like to see a "permanent" bumper mounting for the radar antenna.	None.
5. Traffic Flow				
A. Percent of drivers 5 mph over limit	Troopers said it depended on the time and location. However, they felt about 10% of drivers exceeded speed limit by at least 5 mph.	Same as for Gatso.	No information.	Same as for Gatso.
B. Did drivers slow down?	Yes. Some drivers even stopped to inquire "what was going on."	Yes, mainly after the flash went off. One driver slowed down after he went through the radar beam possibly because his radar detector went off.	Yes. Some troopers saw brake lights after the flash was initiated. Occasionally, some drivers stopped to inquire about the testing.	No reported occurrences.
C. CB traffic	Yes. Some drivers thought the unit was an old type of radar device; others commented that the police were taking pictures.	None reported.	One state reported a lot of CB traffic - some of it derogatory and some wondering what kind of survey was being conducted.	None reported.
D. Adverse reaction	Very little. A few inquiries about the testing were received at the local patrol headquarters and only one motorist complained about his picture being taken.	None reported. Cabinets did not receive any vandalism damage.	Very little except for some derogatory CB traffic. The flash startled one trooper going by the testing area - he didn't know the testing was being conducted.	Only a few public inquiries were received; and only one motorist complained of the testing activities.

TABLE 2 (concluded)

Item	Gatso Mini Radar	Multanova	Traffipax	Truvelo
6. General Impressions About Equipment				
A. Detection system	Troopers felt the detection system was accurate, when the unit was working. Most all felt system could be designed better from an operational standpoint.	Troopers felt the detection system was very accurate and rated it an effective instrument. They thought the calibration was difficult and the components were very bulky.	Some troopers found it hard to adjust the angle of the radar antenna, especially at night. Could not detect vehicles in fourth lane.	Troopers felt the detection system was accurate and selective in its identification of speeders.
B. Photographic system	Liked the automatic exposure control on the camera; however, thought the camera took poor quality pictures during cold weather.	Liked the automatic exposure control on the camera and thought the camera took good quality photographs. The small frame count and film transport indicator discs on top of the camera were difficult to use.	Did not like the flash and/or camera unit being triggered when the police radio mike was keyed. Liked changing film in car rather than outside.	Troopers did not like the photographic system. Thought camera should have automatic exposure control to avoid inappropriate f-stop settings being used.
7. General Impressions About Deployment Strategy Used	Device could be used now with a stop team. There is some risk of a single operator, in responding to an emergency call, driving away from an enforcement area leaving all or part of the equipment behind.	Like the fully automatic operation because it freed the trooper to handle other important operations. Thought the cabinets installed in an area would create a "halo effect" which would have a positive influence on slowing down traffic.	Troopers from one state thought device was an effective tool for speed enforcement while troopers from another state, generally, did not like the device. There was some concern that the radar antenna could be forgotten and run over.	Troopers felt the equipment was too bulky for practical speed enforcement use. Also, felt that placing and removing roadway cables was extremely dangerous.
8. How Does Device Compare with Others Tested	Two state police agencies liked the Gatso least of three tested. Other agency thought the Gatso was better than the Traffipax and Truvelo, but not as good as the Multanova.	Majority of troopers thought the the Multanova was the best of the devices tested.	One state thought the Traffipax was the most mobile of all the devices tested. Another state ranked it second behind the Multanova.	Liked Truvelo least of four devices tested.
9. Overall Comments	None.	Some troopers questioned whether automatic speed enforcement (without an officer in attendance) will ever be legally accepted. Also, they expressed concern if we started using photographic evidence, it might result in other speeding cases, not involving photographic evidence, being thrown out of court.	One state expressed a concern that the device is not readily transferable from vehicle to vehicle, but limited to the vehicle in which it is installed.	None.

* CB or police radio transmission did not cause interference with speed detection by the Gatso, Multanova or Truvelo devices. However, the flash and/or camera unit of the Traffipax was triggered when a police radio mike, either in the Traffipax car or a patrol car alongside the Traffipax car, was keyed.

* Malfunctions and/or breakdowns were noted for all the devices. Film jamming, especially in cold weather, was reported for the Gatso and Multanova devices.

* Significant weather problems were noted for each device. The film used by the Gatso, Multanova and Truvelo devices became brittle and broke on several occasions during cold weather. The Gatso could not be used in rain because it was not waterproof, and its associated radar would not operate at temperatures at or below 15°F. The front windshield of the Traffipax car would fog up during winter because the car's defrost or heat control could not be used while the radar was operating. The road cables of the Truvelo device became very stiff and brittle when operated at below freezing temperatures.

* Troopers did not like setting the Gatso and Truvelo devices outside the vehicle and parking close to the unit and roadway, especially at night. They thought the flash used by each device was very bright, but only the flash used by the Traffipax device to be a potential distraction hazard on two-lane roads.

* Reasonable engineering improvements were suggested for each device that would help overcome some of the devices' operational deficiencies. A typical suggestion was that the units be more compactly designed to enhance their portability/ mobility.

* Under normal conditions, all but the Truvelo could be dismantled and stored by one person in less than 10 min time. Only a few minutes were required under emergency conditions to tear down all but the Truvelo. The troopers felt that the tear down time of the Truvelo, especially its roadway cables, was too long for economical speed enforcement operations.

* Again, reasonable engineering improvements were suggested for all but the Truvelo that would help overcome tear down deficiencies.

* Most troopers said some drivers slowed down as they passed the detection site, especially at night after the flash went off.

* CB traffic regarding the detection operations was only reported when the Gatso and Traffipax devices were used.

* Little to no adverse reaction was received from the drivers during the testing.

* Most troopers felt the detection systems were very accurate and selective in the identification of speeders. However, they felt a number of improvements should be made on some of the devices to make them better from an operational standpoint.

* The troopers felt it was important that the photographic system have an automatic exposure control. They thought the Gatso took poor quality pictures during cold weather and did not like the Traffipax's flash and/or camera unit being triggered when the police radio mike was keyed.

* The troopers felt the Gatso device could be effectively used with a stop team. They liked the fully automatic operation of the Multanova and felt the presence of Multanova cabinets installed in an area would create a halo effect deterring speeding. Mixed opinions were received on the Traffipax, while the troopers felt the Truvelo equipment was too bulky and the sensor deployment too dangerous for practical speed enforcement use.

* A majority of the troopers thought the Multanova to be the best of the devices tested. The Truvelo was liked the least.

* Only a few overall comments were received. These mainly pertained to concerns about the future acceptance of the equipment.

Comments were also received from the commanders/supervising officers involved with the preliminary law enforcement tests. These comments are presented in Table 3 and briefly restated below:

* Generally, the commanders thought the ASE concept to be excellent.

* The commanders felt the most effective deployment strategy was to use the devices in a fully automatic mode of operation.

* The vicarious liability aspects of sending speeding tickets to registered vehicle owners would be a legal/legislative issue that would need to be resolved in each state.

* The commanders all agreed that public acceptance of ASE would depend on a good public information and education campaign.

* The commanders felt the troopers would more readily accept the ASE concept if it were also accepted by the public.

TABLE 3.-SUMMARY OF COMMENTS FROM COMMANDERS/SUPERVISING OFFICERS INVOLVED WITH THE PRELIMINARY LAW ENFORCEMENT TESTS

Item	Commander's/Supervising Officers' Comments
1. General feelings about different devices	Generally, the commanders thought the ASE concept to be excellent. They all agreed the devices tested, albeit very accurate and selective in their identification of target vehicles, are quite bulky and need to be modernized. The commanders liked the Multanova best. They also thought the Traffipax has some merit because of its mobility and could be improved by mounting the camera on the outside of the enforcement vehicle
2. General feelings about deployment strategies	The commanders felt the most effective deployment strategy was to use the devices in a fully automatic mode of operation. From this standpoint, the strategy used with the Multanova was the best, especially when the device was used in combination with multiple roadside cabinets. The commanders also thought the devices that need constant attention or monitoring interfere with other important duties of the troopers, e.g., responding to calls and emergencies while on speed enforcement. The troopers need mobility. Thus, the devices need either to be totally vehicle- or cabinet-mounted.
3. Legal/legislative issues in your state	Vicarious liability aspects of sending speeding tickets to registered vehicle owners would be a legal/legislative issue in each state. The commanders felt owners could be held responsible for speeding offenses if the penalty was changed from a combination of fine, points and potential jail sentence to a fine--similar to a parking ticket. The commanders agreed it would take the states awhile to change the penalties for speeding offenses and impose sanctions on owners. Owner responsibility, outside of parking violations, does exist in some states. For example, New Jersey imposes a fine on owners for observed toll violations ($40 fine).

TABLE 3 (Concluded)

Item	Commander's/Supervising Officers' Comments
4. Public acceptance of ASE in your state	One commander reported that after several hundred hours of operation with the ASE devices, the department had only one citizen complaint. The commanders all agreed that public acceptance of ASE would depend on a good public information and education campaign.
5. Trooper acceptance of ASE	The troopers in two of the three states generally liked the ASE concept. However, most troopers felt that more compact devices should be developed. The commanders felt that the troopers would more readily accept the ASE concept if it were also accepted by the public.
6. State Police acceptance of ASE	The attitude of the three state police agencies toward the ASE concept ranged from open mindedness to conservativeness, or maybe even negativism. One agency believes that any idea, including the ASE concept, that is cost effective in speed enforcement should be explored. The same agency leans toward the use of improved equipment that will yield higher productivity. Another agency thought the ASE concept might be accepted in time, but it would depend on many cost considerations.

* The attitude of the three state police agencies of the ASE concept ranged from open mindedness towards acceptance to conservativeness or slight negativisim.

Table 4 presents a summary of the film reviewers' comments. The comments are divided into seven major categories covering: film processing, readability of data chamber, determination of target vehicle, readability of license plates, determination of owner, time to review film and record results, and suggested improvements. Some of the major findings in Table 4 are enumerated below:

* No problems were encountered in the processing of the film.

* The Truvelo was the only device to have problems associated with the readability of the data chamber elements. The data recorded on the white plastic data tabs could not be read from many of the photographic frames and the speed reading was not very clear on many of the frames.

* Generally, no problems were encountered in determining the target vehicle.

* Many problems were encountered in trying to read the license plates of violating vehicles, irrespective of the device. Generally, the reviewers could not read the plates of violating vehicles in lanes beyond the second because of the distances involved. A high percentage of the film taken with the Truvelo and Multanova devices were improperly exposed. For all devices, the name of the state and the expiration date on the plate were almost always too small to be read, even for vehicles in the first lane. The state identification had to be guessed from the format of data on the plate. The use of color film in place of manufacturer-recommended black and white film improved the readability of license plate. This is further discussed in Appendix A.

* Vehicle owners could be identified in over 90% of the cases where the license plate number could be read and the state identified.

* Between 0.75 and 1.5 man-hours was required to read a roll of 36 exposures taken with an automatic exposure control, to run a records check, and to record the required data. More time was required to review the film taken by the Truvelo because of the exposure problems.

* A suggested improvement common to all devices was the use of a longer focal length lens so that state identification and expiration data on the license plates could be read and the license plate numbers on vehicles in the second lane could be consistently read. The users of the Truvelo also suggested the photographic system be redesigned to include an automatic exposure control.

TABLE 4.-SUMMARY OF FILM REVIEWERS' COMMENTS

Item	Gatso Mini Radar	Multanova	Traffipax	Truvelo
1. Film Processing	No problems. Smoothest part of operation.	No problems	No problems.	No problems.
2. Readability of Data Chamber	Good, no problems.	Good, no problems.	Good, no problems. The digital data code showed up very clearly on the film negative.	The data recorded in ink on the white plastic data tabs could not be read from many of the photographic frames. Also, the speed reading was not very clear - either blurred or very dark - on many of the frames. The clock readings, however, always showed up very well.
3. Determination of Target Vehicle	If two or more vehicles were in the same violator area of the template, it was impossible to identify the violating vehicle. Otherwise, had no problems in identifying target vehicle.	No problems. Didn't have to use template to identify target vehicle.	No problems, generally.	No problems reported.
4. Readability of License Plates	Could not read plates of violating vehicles in third or fourth lane. Sometimes plates on vehicles in second lane could not be read. Name of state and expiration date were almost always too small to be read, even in first lane. Had to guess the state from the format data on the plate. Plates in recessed areas, bent plates and trailer hitches were other reasons why plates could not be read. Also had problems reading some trailer plates. On the average, about 70% of the license plates were totally readable (excluding state and expiration date labels) under a variety of test conditions.	Many of the rolls of film were improperly exposed. Consequently a lot of problems were encountered in trying to read the plates. Plates most frequently identified were on vehicles in first lane. For the rolls where some of the plates could be identified, the percentage of license plates totally readable (excluding state and expiration date labels) ranged from an average of 23% in one state to 33% in another. Use of color instead of black and white film almost doubled percentage of plates totally readable.	Same readability problems as noted for Gatso. For the rolls where some of the plates could be identified, the percentage of license plates totally readable (excluding state and expiration date labels) ranged from an average of 23% in one state to average of 20% in one state to 70% in another. The low percentage obtained by one state was attributed to improper exposure problems.	High percentage (94%) of the film was either under or overexposed. For the properly exposed rolls of film, the plate numbers and letters were identifiable for about 74% of the vehicles, but the state name and expiration date could not be read. The clarity of the plates on passenger cars and single unit trucks was improved when the camera was closer to the roadway cables, but the rear plates of tractor/trailer combinations were then out of camera view. Glare from vehicle brake lights and bright plate lights sometimes overexposed the plate area.

TABLE 4 (concluded)

Item	Gatso Mini Radar	Multanova	Traffipax	Truvelo
5. Determination of Owner	Vehicle owners could be identified in over 90% of cases where plate number could be read. Vehicle owners identified included: private citizens, leasing agencies, business, and governments. Also, it is possible for the owner of a trailer to be different from the owner of the tractor pulling the trailer.	Same as for Gatso.	Same as for Gatso.	Vehicle owners could be identified in 90-100% of the cases where plate numbers could be read.
6. Time Required to Review Film and Prepare Forms	Between 0.75 and 1.5 man-hours to read one roll of 36 exposures, to record data from the film review, and to run and record the results of records checks.	Same as for Gatso	Same as for Gatso	No specific estimate of time was available. However, the process of reviewing the film was very time-consuming because of the exposure problems. The time required to obtain owner identification from automated vehicle registration files is minimal.
7. Suggested Improvements	Use higher wattage (greater than 150 watts) projectors to view the film. Also, consider using photographic prints in the film analysis stage. Need to use longer focal length lens so that state identification and expiration data on the license plates could be read.	Same as for Gatso.	Same as for Gatso. Also, use of vehicle defogger during radar operation in the winter time might help improve clarity of photographic negatives.	Same as Gatso. Also, the camera should be redesigned to include an automatic exposure control.

VIII. COMPARISON OF SELECTED ASE DEVICES

This section brings together information and data obtained during the contract for the purpose of making comparative ratings of the selected ASE devices and enforcement strategies. The intent is to suggest the potential utilities and shortcomings of the device/deployment combinations in the U.S., using a numerical scheme. The initial results are discussed here; the details and their justification are in Appendix B.

Eighteen device/deployment combinations are considered. To enable comparison with existing, common practices, the first combination consists of a stationary, American, down-the-road radar used by a single officer, who pursues and stops detected violators. The same radar used in conjunction with a three-man stop team is also examined.

The four selected ASE devices, each used in selector ways, are analyzed. The Gatso, Multanova, Traffipax, and Truvelo systems are compared in manned operations using stop teams, both with and without photographic backup, as well as without a stop team and relying just on the photographic evidence. Finally, both the Gatso and Multanova systems are examined using fully automatic, unmanned, fixed installation strategies. The unmanned operations are compared first with the devices using their supplied 75 mm camera lens, and then with the devices using substituted 135 camera lens. The use of the longer focal length lens demonstrates the potential value of improving the readability of the vehicle license plates from the photographic negatives.

Five rating categories are used, and each is given two scores (see Table 5). The first of each pair of scores represents a best estimate for the category based upon available information. The second (lower) score reflects the level of uncertainty due to lack of controlled experiments, U.S. experience, etc. In all cases a perfect score is 1.0, and 0.0 represents the worst possible result.

The first rating category listed is technical effectiveness. The scores shown account for 10 different factors that contribute to the technical abilities of the system. Included are the basic ability of the systems to detect speeding, accuracy, ability to identify the offending vehicle, freedom from motorist evasion tactics, environmental limitations, and other considerations. The acceptability scores, listed next, incorporate legal, judicial, police, and public acceptance factors. Cost factors include capital expenses, installation costs, maintenance and repair, operational manpower, and other operational costs. The operational effectiveness scores combine the acceptability and technical effectiveness issues; the cost effectiveness scores also include the cost factors. Detailed definitions are in Appendix B.

Of all the systems considered, the American down-the-road radars score lowest in technical effectiveness. The other systems do not differ appreciably from one another, but do differ substantially according to the deployment strategy used. In general, all of the systems improve in effectiveness, technically, as more automation is added. The highest technical effectiveness score is achieved by the Multanova when equipped with a

TABLE 5.-NUMERICAL RATING SUMMARIES[a]

System[b] / Strategy[d]	1 / 1	1 / 2	2 / 2	2 / 3	2 / 4	2 / 5	2[c] / 5	3 / 2	3 / 3	3 / 4	3 / 5	3[c] / 5	4 / 2	4 / 3	4 / 4	5 / 2	5 / 3	5 / 4
Technical Effectiveness	0.53	0.57	0.65	0.67	0.76	0.76	0.80	0.68	0.68	0.73	0.77	0.86	0.68	0.69	0.77	0.74	0.75	0.81
	(0.49)	(0.51)	(0.61)	(0.63)	(0.71)	(0.67)	(0.69)	(0.64)	(0.65)	(0.70)	(0.72)	(0.78)	(0.64)	(0.65)	(0.72)	(0.69)	(0.68)	(0.71)
Acceptability	0.93	0.89	0.81	0.84	0.58	0.52	0.52	0.83	0.86	0.61	0.56	0.57	0.82	0.85	0.59	0.84	0.85	0.60
	(0.88)	(0.68)	(0.59)	(0.54)	(0.32)	(0.24)	(0.24)	(0.61)	(0.56)	(0.34)	(0.31)	(0.33)	(0.66)	(0.55)	(0.33)	(0.62)	(0.56)	(0.32)
Cost	0.88	0.86	0.86	0.62	0.61	0.51	0.51	0.71	0.58	0.56	0.47	0.45	0.82	0.60	0.59	0.86	0.75	0.73
	(0.84)	(0.79)	(0.82)	(0.57)	(0.57)	(0.40)	(0.38)	(0.67)	(0.53)	(0.52)	(0.44)	(0.42)	(0.78)	(0.55)	(0.55)	(0.82)	(0.70)	(0.69)
Operational Effectiveness	0.49	0.51	0.53	0.56	0.44	0.40	0.42	0.56	0.58	0.45	0.43	0.49	0.56	0.59	0.45	0.62	0.64	0.49
	(0.43)	(0.35)	(0.36)	(0.34)	(0.23)	(0.16)	(0.17)	(0.39)	(0.36)	(0.24)	(0.22)	(0.26)	(0.42)	(0.36)	(0.24)	(0.43)	(0.38)	(0.23)
Cost Effectiveness	0.43	0.44	0.45	0.35	0.27	0.20	0.21	0.40	0.34	0.25	0.20	0.22	0.46	0.35	0.27	0.53	0.48	0.35
	(0.36)	(0.27)	(0.30)	(0.19)	(0.13)	(0.06)	(0.06)	(0.26)	(0.19)	(0.12)	(0.10)	(0.11)	(0.33)	(0.20)	(0.13)	(0.35)	(0.27)	(0.16)
Cost per Arrest ($)[e]	4.46	4.15	4.32	6.19	1.09	1.01	0.84	4.45	6.10	1.60	1.20	0.73	4.33	6.25	1.09	4.17	5.75	1.10

[a] Primary numbers are "best estimates." Values in parentheses are lower and reflect the effect of uncertainty in the various steps of the rating process. A perfect score is 1.00.

[b]
1: Stationary, American, down-the-road radar.
2: Gatso Mini Radar MK4.
3: Multanova 4FA.
4: Traffipax IV/R.
5: Truvelo Model 4.

[c] Device equipped with a 135 mm camera lens in place of the supplied 75 mm lens.

[d]
1: Single officer, who pursues and stops violators.
2: One officer manning detection system plus 3-officer stop team down the road.
3: Same as (2), plus supplementary photographic documentation.
4: Manned, automatic operation; no stop team, mailed notices.
5: Unmanned, fully automatic operation.

[e] Based on a set of uniformly applied assumptions described in Appendix B, which include no presumed differences in deterrence effect other than in case of unmanned, fully automatic operations, with fixed installations.

135 mm camera lens (in place of the standard 75 mm lens supplied with the camera) and used in an unmanned, fully automatic mode of operation. The Gatso, because of its operational problems, does not rate as high as the Multanova when used in an unmanned, fully automatic mode of operation.

The ranking situation is essentially reversed with regard to the acceptability scores. The most acceptable is the American down-the-road radar. The Truvelo was the least liked by the police and consequently received the lowest police acceptability score of all the four ASE devices tested. However, when the police acceptability score was combined with the other three acceptability scores (legal, judicial and public) the four ASE devices are about equally acceptable when used with a stop team. All the ASE systems receive substantially lower scores when photographic evidence is relied upon, because of the legal problems associated with identification of the driver. It is emphasized that all the acceptability scores of the four ASE devices are very tentative because the devices are relatively unknown and untried in the U.S., except for the preliminary law enforcement testing described in this report.

The cost category, by itself, is as one might expect. The cheaper, less automated systems score higher (lower cost), and the more expensive, fully automated systems score lowest. However, these scores do not take into consideration the productivities of the systems.

Combining the technical effectiveness and acceptability issues into a single operational effectiveness score tends to make most of the systems appear more equivalent. That is, those that are more effective, technically, tend to receive lower acceptability scores, and vice versa. Overall, the Truvelo system scored highest, because it is apparently quite effective and relatively uncontroversial. The Gatso system when used in an unmanned, fully automatic mode of operation scored lowest, because of the fairly low acceptability scores. The Multanova equipped with a 135 mm lens and used in an unmanned, fully automatic mode of operation scored the same as the American down-the-road radar used by a single officer and almost the same as the American down-the-road radar use in connection with a stop team.

When cost considerations are included, the Truvelo system used with a stop team scored the highest. The cost effectiveness of each system decreased as more automation is added. The fully automatic systems scored lowest, because of the fairly low acceptability and cost scores.

One problem with the rating system, as described in Appendix B, is the difficulty in devising a logical, consistent method of assigning weights to the various categories and factors within categories. For example, should one place higher weight on cost, on acceptability, or on technical effectiveness? These judgments must ultimately be made by administrators taking other factors such as budget limitations, local political concerns, etc., into account.

Another way of treating these data, however, is to examine cost-effectiveness ratios. Such data are shown at the bottom of Table 5. These figures are estimated enforcement costs per arrest, based on the data given in more detail in Table 6. The rationale behind these costs is given in the following paragraphs.

TABLE 6.-ANNUAL COST IMPLICATIONS AND COST PER ARREST FOR EACH SYSTEM - STRATEGY COMBINATION INVESTIGATED

			Annualized Costs ($)							
Case	System[a]	Strategy[b]	Capital Equipment	Installation	Maintenance/ Repair	Non Manpower Operation	Manpower Operation	Total	Annual Arrests	Cost/ Arrests
1	1	1	443	0	500	450	12,000	13,393	3,000	4.46
2	1	2	443	0	500	900	48,000	49,843	12,000	4.15
3	2	2	1,889	0	1,000	900	48,000	51,789	12,000	4.32
4	3	2	4,011	0	500	900	48,000	53,411	12,000	4.45
5	4	2	2,444	100	500	900	48,000	51,944	12,000	4.33
6	5	2	417	0	700	900	48,000	50,017	12,000	4.17
7	2	3	3,947	0	1,000	9,307	60,000	74,254	12,000	6.19
8	3	3	7,039	0	500	5,652	60,000	73,191	12,000	6.10
9	4	3	4,705	150	500	9,682	60,000	75,037	12,000	6.25
10	5	3	1,464	0	700	6,858	60,000	69,022	12,000	5.75
11	2	4	3,947	0	1,000	19,589	36,521	61,057	55,908	1.09
12	3	4	7,039	0	500	9,808	23,088	40,435	25,281	1.60
13	4	4	4,705	150	500	20,462	37,613	63,430	58,393	1.09
14	5	4	1,464	0	700	14,335	29,381	45,880	41,885	1.10
15	2	5	3,947	1,770	4,000	14,769	29,841	54,327	53,672	1.01
16	3	5	7,039	1,770	3,500	14,124	17,367	43,800	36,404	1.20
17	2[c]	5	4,018	1,770	4,000	17,606	29,841	57,235	67,856	0.84
18	3[c]	5	7,110	1,770	3,500	29,856	41,314	83,550	115,063	0.73

[a] 1: Stationary, American, down-the-road radar.
2: Gatso Mini Radar MK4.
3: Multanova 4FA.
4: Traffipax IV/R.
5: Truvelo Model 4.

[b] 1: Single officer, who pursues and stops violators.
2: One office manning detection system plus 3-officer stop team down the road.
3: Same as (2), plus supplementary photographic documentation.
4: Manned, automatic operation; no stop team, mailed notices.
5: Unmanned, fully automatic operation.

[c] Device equipped with a 135 mm camera lens in place of the supplied 75 mm lens.

The down-the-road radar systems were amortized over 5 years; the other systems over 10 years based on European experiences. In both cases, amortization was calculated using a 12% interest rate. The resulting values, as shown in Table 6, were used to determine the first of the five cost factors in the rating system.

None of the systems other than the Traffipax and the fully automatic, unmanned systems entail appreciable installation costs. An annual cost of $100 is assumed for the Traffipax system without a camera. This value is increased by $50 when the camera is included in the system. A total cost of $10,000 was used for the unmanned systems, again amortized over 10 years, to cover such items as an enclosure, support pad, power, etc.

Normal maintenance and repair costs for the American down-the-road radar and the Multanova and Traffipax systems should be fairly minor. A figure of $500 per year was used for this factor. The maintenance and repair costs for the Gatso and Truvelo systems should be higher based on the engineering and law enforcement field test experiences. A figure of $1,000 per year was used for the Gatso, while $700 per year was used for the Truvelo. An extra maintenance and repair cost of $3,000 per year was assumed for the unmanned installations to account for anticipated vandalism.

The operational costs other than manpower, included in the fourth cost factor, depend on the number of arrests made. For the deployment strategies using pursuit or stop teams, it was assumed that a 3-man stop team made 12 arrests per hour, and the lone officer engaging in detection/pursuit/stop activities made 3 arrests per hour for the scenario previously described. The number of arrests to be made using the photographic systems, for the same scenario, depends upon the percentage of speeders detected and photographed, the percentage of license plates totally readable, and the percentage of vehicle owners that can be identified from readable plates and through state vehicle registration records. For the Gatso system these percentages were assumed to be 70, 70, and 95, respectively. For the Multanova system these percentages were assumed to be 79, 28, and 95, respectively. For the Traffipax system these percentages were assumed to be 73, 70 and 95, respectively. For the Truvelo system these percentages were assumed to be 50, 74 and 95, respectively. When the 135 mm camera lens was used with the Gatso and Multanova systems in place of the supplied 75 mm lens, the percentage of license plates totally readable was assumed to increase to 89%.

Cost figures used with the above assumptions in the non-manpower operations included film purchase and processing (10¢ per frame for the 36 exposure cassettes, 5¢ per frame for the bulk film); 20¢ per case for mailing expenses; 15¢ per mile for vehicle expenses associated with pursuit and the operation of the stop team.

It was assumed that the attended systems were in operation 20 hr per week and 50 weeks per year, but that the unattended Multanova system was in effective operation 16 hr a day, 300 days per year. The unattended Gatso system was assumed to be down for repairs about one-third the time it was scheduled to be used. It was further assumed that the location of the unmanned, fully automatic systems would soon be known to much of the motoring public, so that only 30% as many speed violations would occur. The results from all of these assumed criteria are given in Table 6.

Finally, the enforcement (trooper) manpower costs were determined on the basis of $12 per man-hour. Applying the previous assumptions, the manned operations involved 1,000 man-hours per year to operate the equipment (with an additional 3,000 man-hours per year for the stop teams). Moreover, it was assumed that an additional 1,000 man-hours were required to handle extra work required as a result of challenges to the photographic data acquired in connection with the stop teams. The manned, automatic operations, in addition to requiring 1,000 man-hours per year of a trooper to operate the equipment, also required a police clerk, at $7 per hour, to review the film. It was assumed for all but the Multanova that about 2.5 min per case would be required to read the film and transfer the data to a computer or appropriate coding forms. It was assumed that about 1 min per case would be required to read the Multanova film and encode the data because of the poor quality of the photographic evidence obtained by this device and its 75 mm camera lens. The unmanned, fully automatic operations required the same amount of police clerk labor to review and analyze the film as in the manned, automatic operations. However, in place of the 1,000 man-hours per year of a trooper to operate the equipment, it was assumed that 900 and 200 man-hours per year of a police clerk would be needed for the Gatso and Multanova systems, respectively, to retrieve and load the film and check the unit. When the Multanova was equipped with a 135 mm camera lens, it was assumed that about 2.5 min per case, instead of 1 min per case, would be required to read the film and encode the data. No additional manpower charges were incurred with the Gatso system when used with a 135 mm camera lens.

The assumptions are compatible with those used to develop the ratings. It is particularly important to note it was assumed that, other than with the fully automatic, unmanned operations, none of the system/strategy combinations has more deterrent effect than the others. That is, the number of speeders subject to arrest is the same in each case. A substantially greater compliance (fewer speeders) was assumed for the fully automatic systems because the public will become aware of the fixed installation locations.

The results of this analysis show that the manned operations <u>not</u> using photography yield a cost estimate of somewhat over $4.00 per arrest, regardless of the system used. When photography is added, but the manned stop teams remain, the cost increases to between $5.75 and $6.25 per arrest. Eliminating the stop teams, but adding cost for processing film, locating owners, etc. (e.g., mode 4 in Table 6) reduces the total enforcement costs to between $1.09 and $1.60 per arrest, primarily because of the substantially larger number of arrests that are possible with less manpower. The fully automatic systems equipped with a standard 75 mm camera lens yield a cost estimate of between $1.01 and $1.20 per arrest. However, the fully automatic systems equipped with a 135 mm camera lens have the lowest cost per arrest of any--between $0.73 per arrest for the Multanova and $0.84 per arrest for the Gatso, based on the assumptions used.

Finally, the subject of compliance--the degree to which speeding is reduced--must be addressed. This, not the number of arrests, is the ultimate measure of effectiveness (next to accident reduction and energy savings). Unfortunately, little data exist on which to judge foreign success in this regard; and no information is available for U.S. experience with these systems. This subject, then, remains as a primary need for future study.

IX. ASE IMPROVEMENTS FOR U.S. IMPLEMENTATION

This section presents recommended improvements to selected ASE approaches that are appropriate for implementation in the U.S. Both devices and enforcement strategies are considered. These recommendations are based upon the data collected during the engineering and preliminary law enforcement tests. Presented first are some general recommendations that pertain to all the four ASE devices tested. These comments are followed by specific recommendations for each of the four devices. Finally, recommendations are given concerning ASE strategies potentially appropriate for use in the U.S.

Four improvements are recommended that are common to all four ASE devices tested. First, the device cameras should be equipped with a longer focal length lens (longer than the standard 75 mm lens supplied with the cameras) so that state identification and expiration data on the license plates can be read. This improvement would also allow for the more consistent identification of license plate numbers on vehicles in the second lane from the camera. Engineering tests conducted with different camera lens lengths indicated a 135 mm lens would be an acceptable replacement for the 75 mm lens supplied with the devices.

Secondly, the device cameras need to be reexamined to correct the problems they had with film during cold weather. Many times at temperatures below freezing, the film became brittle and sprocket holes tore resulting in film jamming. A small, thermostatically controlled heater placed in the near vicinity of the camera could potentially solve, or ameliorate, the brittleness problem.

The third general recommendation addresses the need to have the devices' cable connection operations simplified. This can be accomplished both by color coding the connector cables (as is done with the Multanova) and by using different types of connectors that are more easily used, especially in cold weather. The lengths and, in some cases, the gauge of the connector cables should also be modified (reduced).

Lastly, the devices tested are somewhat bulky and in need of modernization to make them more compact. This design change would enhance their portability/mobility requirements.

Recommendations specific to each device tested were also generated. These are listed below:

- <u>Gatso Mini Radar Model MK4</u>: The detection portion of the Scott radar subsystem needs to be reexamined to isolate and remove the direction sensing problems encountered during both the engineering and preliminary law enforcement testing.

The device needs to be redesigned to make it less susceptible to weather problems. The design of the unit tested was such that it could not be operated unprotected out-of-doors during rain or snow. Also, the Scott radar would not operate at temperatures at or below 15°F. These weather related problems, as well as the trooper's dislike for placing the unit outside the vehicle and parking close to the unit and the roadway, could be resolved by installing the device inside an enforcement van such as is done by the Rotterdam (Netherlands) City Police.[7] This type of installation would also help overcome trooper complaints that the device's mobility was restricted by too much time being required for setup and tear down.

- Multanova Model 4FA: The photographic subsystem needs to be reexamined to correct the cause of the excessive, improper film exposure encountered during the preliminary law enforcement testing. These problems were not evident during the engineering tests.

- Traffipax Type V/R: The assembly and installation requirements for the Traffipax need to be greatly simplified. A large effort, including preparing the cables interconnecting some components was needed, before the system could even be acceptance tested. Also, a considerable amount of time was required to install the device in an enforcement vehicle. The extensive installation time was required because the system is designed for semi-permanent mounting in the vehicle. Thus, the system cannot be moved readily from vehicle to vehicle without some design changes being made.

The arrangement for mounting the Traffipax camera on the police vehicle dashboard also needs to be redesigned. The camera-mounting bracket supplied with the device did not fit the dash of the American-made vehicle used in the preliminary tests. When modified to fit the contours of the dash, the hood of the vehicle was in the field of view. Consequently, a new mounting bracket had to be fabricated. The replacement camera mounting was satisfactory from a photographic standpoint, however, it was considered by law enforcement personnel to be a potential injury-producing hazard to vehicle occupants in the front seat. Exterior mounting of the camera should be considered.

The SFIM radar unit of the Traffipax has five preselected speed settings. The unit tested during the study had metric settings which were not appropriate to law enforcement testing in the U.S. Even though nonmetric speed settings are available on request, the design feature of providing preselected speed settings for enforcement is not convenient from an operational standpoint. For the system to have greater enforcement flexibility, the radar unit should be redesigned to accommodate a variable speed setting.

The Traffipax's control unit and associated connector cables need to be better protected from external signals. The flash and/or camera unit was triggered when a police radio mike, either in the Traffipax vehicle or a patrol car alongside the Traffipax vehicle, was keyed.

Finally, it is recommended that the radar power supply system be redesigned so the Traffipax vehicle's engine can be running during radar operation. The radar operates from a separate battery to avoid any possible electrical interference with any automobile components. When the radar is in operation, this battery and its circuitry are totally disconnected from all the electrical circuits of the vehicle. However, the relays under the hood automatically connect this battery to the vehicle's alternator (and disconnect it from the radar) when the vehicle's engine is running, to keep the battery charged. This recommended redesign would allow the vehicle's heater and defroster be used during radar operation.

- Truvelo Model 4: The photographic subsystem should be redesigned from two additional standpoints. First, the camera needs to be equipped with an automatic exposure control. Secondly, the readability of the data chamber elements needs to be improved.

The road cables used with the Truvelo also need to be reexamined to see if their lower temperature operating limit can be extended. Also, the outer protective insulation of the road cables was subject to shredding when exposed to heavy truck traffic during cold and wet weather.

Finally, recommendations were also developed concerning ASE strategies potentially appropriate for use in the U.S. These recommendations are based on the need for speed enforcement personnel to have mobility for a number of reasons: for responding to an emergency call; for handling other important operations; and for changing locations easily, especially, when certain areas are unproductive. The most effective deployment strategy to satisfy the first two needs is to use the devices in a fully automatic mode of operation. From this standpoint, the strategy used with the Multanova is recommended, especially when it is used in combination with multiple roadside cabinets. Installing multiple cabinets over an enforcement area and periodically moving the device from cabinet to cabinet would create a "halo effect" which could suppress traffic speeds throughout the area. The drivers would not know which cabinet was "active" and which cabinets were non-functioning.

A strategy that would satisfy the need to easily change locations is to use a vehicle-mounted device, such as the Traffipax or Gatso, in combination with a stop team. A vehicle-mounted device would provide the mobility required to quickly move from area to area.

The Truvelo has limited usefulness in the U.S. for speed enforcement on heavily traveled, state-controlled routes where the speed limit is 55 mph. This is because of the hazard associated with the placement of the roadway cables and the impediment to mobility associated with the equipment. Perhaps the greatest potential usefulness of this type of device for speed enforcement in the U.S. is in conjunction with a stop team on urban streets where the speed limits are much less than 55 mph. This is the application found useful by the London Metropolitan Police.

X. CONCLUSIONS

The subject of speed enforcement, and more specifically automated speed enforcement, is of widespread interest--not just to the federal government, but to the numerous law enforcement agencies in the United States as well. This report contains much information with which most such agencies are probably not familiar. Additional information on extant technological advancements that have been, or potentially could be, applied to speed enforcement are described in detail in the Interim Report.[7]

The following are the major conclusions that the authors developed, in consideration of all the information obtained during the study.

1. Most drivers speed, at least occasionally, potentially creating safety problems or making less efficient use of limited petroleum-based energy sources. More effective law enforcement (as well as other actions) could help to deter this behavior.

2. Applied technology, especially automated speed enforcement (ASE) devices, is important to the future of law enforcement, and provides an approach for improving compliance with speed laws.

3. A common technology, Doppler radar, is routinely used in the United States for speed enforcement. As employed in the American devices, however, it has several technical drawbacks. Among these are its inability to identify speeding vehicles, the occasional need for officer judgment, its susceptibility to interference, and its early detectability by potential violators.

4. A great deal of technology exists in the world that, although potentially useful, has not yet been applied to speed enforcement in the United States.

5. Most of the existing devices identified in this study that are applicable to speed enforcement are not American--they are European, Japanese, Australian, etc.

6. Much of the identified technology potentially applicable to speed enforcement has, in fact, been widely used routinely for this purpose throughout the world.

7. One of the most promising technologies is Doppler radar directed diagonally across the road. The so-called cross-the-road systems, which are more sophisticated (and costly) than American radar systems, are more commonly used in Europe and elsewhere (outside the United States) than are the American systems.

8. Among the advantages of the cross-the-road radar systems are their greater selectivity, far superior capability of detecting speeding in heavier traffic, ability to identify speeding vehicles, freedom from human error and external interferences, and effective indetectability by radar detectors.

9. Many of the identified technologies, including the cross-the-road radars, are very versatile in that they can be deployed in a variety of configurations for speed enforcement purposes.

10. All ASE devices have one feature in common--they have the capability of being coupled with a camera system to obtain photographic evidence of speeding violations. The detection portions of the devices employ various methods for making speed measurements, but the most common is cross-the-road Doppler radar. Many of the ASE devices are capable of being deployed in fully automatic, unmanned operations, freeing police officers for other functions.

11. The engineering field tests conducted with four selected ASE devices (Gatso Mini Radar Model MK4, Multanova Model 4FA, Traffipax Type V/R, and Truvelo Model 4) were sufficient to obtain necessary operational familiarity with the systems and to establish bounds and limitations on the capabilities of the systems. No one system was found superior in all the 19 tests conducted.

12. The use of a longer camera lens (longer than the standard 75 mm supplied with the device cameras) greatly enhances the readability of the U.S. license plates from the photographic negatives. The incremental improvement between a 75 mm lens and a 135 mm lens was greater than the incremental improvement between a 135 mm and 200 mm lens.

13. The use of color film (as opposed to the manufacturer-recommended black and white film) enhances the positive identification of the state origin of the license plate and improves the readability of some license plates with poor color contrast. The need for more precise exposure settings, however, adversely affects the desirability of using color film in conjunction with a lens longer than 75 mm.

14. There is a need to revise U.S. license plates to increase their readability. This revision is needed even though the use of a longer camera lens and color film enhances the positive identification of currently used plates. The revision should involve increasing the size of the plate, the alpha-numeric code, the state identifier, and the expiration date. Poor color contrast plates should also be avoided. The establishment of a national license plate format and design like those used in other countries should be strongly considered.

15. The preliminary law enforcement field tests conducted with the four selected ASE devices were sufficient to assess the police training requirements; identify potential problems associated with the use of the devices; and to evaluate the general acceptability of the devices by the law enforcement personnel.

16. The troopers involved in the preliminary law enforcement field tests felt that the training manuals developed for the four devices were very useful and easy to follow. They thought the 1-day combined classroom and field training was sufficient for the preliminary tests. However, more extensive training would be needed for all the devices except the Traffipax, if used for enforcement.

17. Malfunctions and/or breakdowns were noted for all the devices during the preliminary law enforcement field tests. Significant weather problems were also noted for each device.

18. Generally, the troopers had something good to say about the operation of each device. A majority of the troopers thought the Multanova to be the best of the devices tested.

19. Reasonable engineering improvements were suggested by the troopers for each device that would help overcome some of the devices' operational deficiencies. A typical suggestion was that the units be more compactly designed to enhance their portability/mobility.

20. The commanders/supervising officers involved with the preliminary law enforcement tests generally thought the ASE concept to be excellent and that the most effective deployment strategy was to use the devices in a fully automatic mode of operation.

21. The commanders agreed that the vicarious liability aspects associated with using ASE devices would be a legal/legislative issue that would need to be resolved in each state. They also felt that public acceptance of ASE would depend on a good public information and education campaign.

22. Vehicle owners could be identified in over 90% of the cases if the license plate number could be read and the state identified. However, many problems were encountered by the film reviewers in trying to read the license plates of the violating vehicles, irrespective of the device. The name of the state and the expiration date on the plate were almost always too small to be read, even for vehicles in the near lane. The state of registration had to be deduced from the format of data on the plate. The use of longer focal length lens was a suggested solution to the readability problems.

23. A number of legal issues have been raised regarding the employment of ASE devices, especially when they involve photography. Most of the concerns have been found not to present formidable legal barriers to their employment in the United States. The one exception is the vicarious liability problem, which arises with photographic systems when only the vehicle owner can be identified (through the license plate), and not the driver. A number of approaches to dealing with this problem are suggested in the study.

24. The public acceptance issues pertaining to the use, or potential use, of ASE devices in the United States are many-faceted and complex. A recent study of the public acceptability of highway safety countermeasures reported an investigation into the acceptability of ASE devices. Unfortunately, the results of the study cannot be used to assess the public acceptance of ASE devices in the United States because of the incorrect interpretations conveyed to those surveyed.

25. In evaluating the effectiveness of any applied technology in speed enforcement, it is necessary to consider not only the technology itself, but also the deployment strategy employed. That is, the device, the officers, and the legal and public opinion environments must be considered together.

26. A numerical rating scheme applied consistently to a number of ASE devices with various deployment strategies lead to the following major points:

- As the systems become more automated their technical ability to detect and identify speeders under a variety of conditions and situations improves; and

- Any system relying primarily on photographic evidence is likely to be less acceptable, either legally or by the public, than if it did not use a camera.

27. Further review of various ASE devices and their deployment strategies shows that the more automated systems are more cost-beneficial than the manned, stationary, American, down-the-road radar systems when viewed on a cost-per-arrest basis.

28. The fully automatic systems equipped with a 135 mm lens would have the lowest cost per arrest of any system--between $0.73 per arrest for the Multanova and $0.84 per arrest for the Gatso, based on the assumptions used.

29. Present (high) capital equipment costs of fully automatic detection systems may become significantly reduced if they are widely accepted and used in the United States.

30. The best measure of the effectiveness of any approach in deterring speeding is the level to which drivers conform to the speed limit. Unfortunately, no data are presently available to help in assessing any of the technologies from this viewpoint.

XI. RECOMMENDATIONS

* Engineering modifications should be made to the ASE devices, as tested, to enhance their portability/mobility and make them less susceptible to adverse weather problems.

* The camera systems used by the ASE devices tested should be modified to use a longer camera lens in the U.S.--longer than the standard 75 mm supplied with the systems.

* The modified ASE devices should undergo additional engineering field evaluations to determine the appropriateness of the modifications.

* The modified ASE devices should be field tested in an operational setting in which the systems are actually employed to issue warnings and, eventually, citations for speeding.

* In support of the operational field testing activity, public information strategies need to be developed that can make the affected public aware of the general concept of ASE devices and associated deployment strategies.

* Model legislation should be developed that will assist jurisdictions in implementing the required legislation to permit field testing of a citation-oriented ASE strategy.

* Comparative data need to be acquired to determine the effectiveness of ASE devices to deter speeding in the U.S.

* U.S. license plates should be revised to increase their readability and to reduce their variability of format and design from state to state.

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APPENDIX A

DETAILS OF ENGINEERING FIELD TESTS

A total of 19 engineering field tests was conducted with four selected ASE devices. The details of each test performed, including purpose, fixed parameters, test setup, and test procedure, are presented in this appendix. Also discussed are the data recorded during each test and the associated data analysis performed. The results of some of the analyses are given in this appendix; the balance is given elsewhere in the report.

1. Test 1 - Effect of Ambient Lighting on Photographic Capability

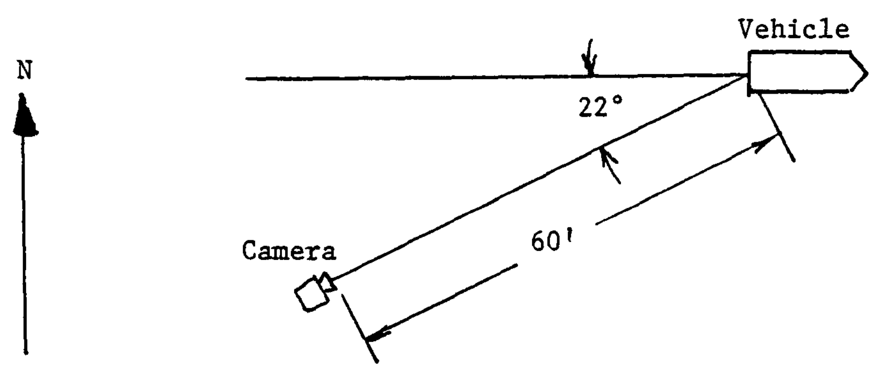
Purpose

The purpose of this test was to exercise the devices' photographic system over a wide range of ambient light intensities to determine their ability to produce adequate photographs without the use of a flash.

Fixed Parameters

Film:	Black and white (B&W) of the type recommended by the manufacturer.
Environment:	Off the road, where controlled tests were possible.
Vehicle:	Stationary automobile with no unusual characteristics, but with an easy-to-see license plate. (Trucks were not considered.)
License Plate:	Clean Missouri plate.
Lighting:	A range of light intensity from bright midafternoon sun through near darkness.

Test Setup



Test Procedure

The vehicle was positioned such that the sunlight directly illuminated the license plate. Two exposures were taken with each photographic system at a number (6-8) of ambient light intensities. The light intensity, as measured by the maximum aperture (f-stop setting) for a 1/500 or 1/30 sec shutter speed (whichever was most appropriate), was recorded using a light meter set for an ASA 400 film speed setting.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: time of day, frame number, f-stop for either a 1/500 or 1/30 sec shutter speed, and general comments. The film was processed to the negative stage and viewed to determine the minimum light level required for complete readability of the license plate number. The minimum light level was indicated by the f-stop setting at 1/30 sec shutter speed with ASA 400 film.

2. Test 2 - Effect of Range on Photographic Capability

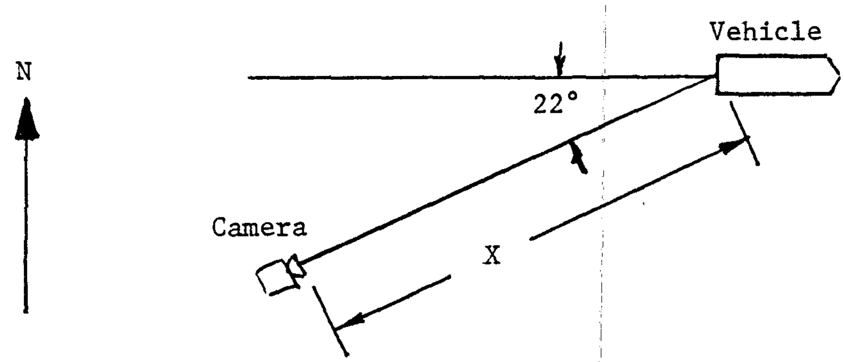
Purpose

The purpose of this test was to determine the range over which adequate photographs could be obtained by the devices under good lighting conditions.

Fixed Parameters

Film:	B&W, of the type recommended by the manufacturer.
Environment:	Off the road, where controlled tests were possible.
Vehicle:	Stationary automobile with no unusual characteristics, but with an easy-to-see license plate. (Trucks were not considered.)
License Plate:	Clean Missouri plate.
Lighting:	Midafternoon sun directly illuminating the license plate.

Test Setup (for midafternoon photos)



Test Procedure

Two exposures were taken at each of the following values of X: 30, 60, 90, 120, 135, and 150 ft. The light intensity, as determined by the maximum aperture for a 1/500 sec shutter speed, was recorded using a light meter set for an ASA 400 film speed setting.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: time of day, frame number, distance, (X), f-stop at 1/500 sec shutter speed, and general comments. The film was processed to the negative stage and viewed to determine the greatest range for complete readability of the license plate under daylight conditions.

3. Test 3 - Effect of Shadowing and Glare

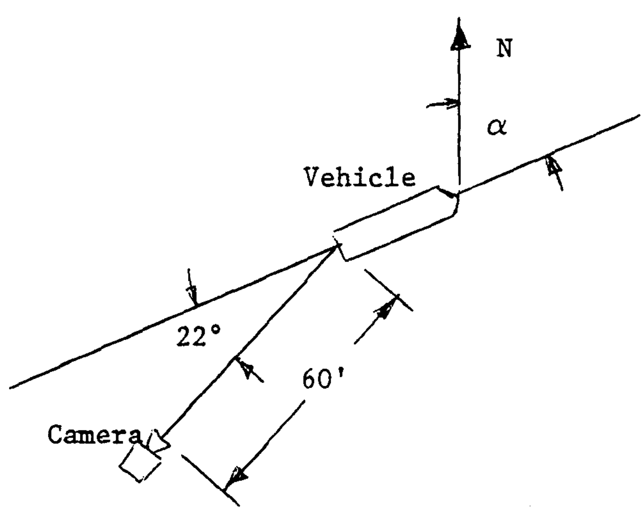
Purpose

The purpose of this test was to determine the readability of license plates from photographs obtained by the devices under shadowing and glare conditions.

Fixed Parameters

Film:	B&W of the type recommended by the manufacturer.
Environment:	Off the road, where controlled tests were possible.
Vehicle:	Stationary automobile with no unusual characteristics, but with an easy-to-see license plate. (Trucks were not considered.)
License Plate:	Clean Missouri plate and a clean Kansas plate.
Lighting:	Bright sunlight

Test Setup



Test Procedure

Test 3 was designed to investigate the influence of various incident lighting angles on the readability of license plates. To accomplish this, the vehicle heading angle, α, measured clockwise from north, was varied in each of three sequences of testing. The sequences as defined below were selected to cover a range of sun elevation positions, i.e., overhead, mid-elevation, and low-elevation position.

Sequence 1: With the sun essentially overhead (Noon - 2:00 p.m.), four exposures (two of each of the two state license plates) were taken at each of 10 equally spaced heading angles (22.5° increment) between 315° and 157.5°. That is α = 315, 337.5, 0, 22.5, 45, ..., 157.5°. For a given setup (given value of α) photographs were taken with all four cameras to assure comparability and to speed set-up time.

Sequence 2: This sequence was the same as 1 above, except the sun was at a mid-elevation position (3:00 p.m. to 4:30 p.m.) and different heading angles of α = 22.5, 45, 67.5, ..., 225° were used.

Sequence 3: This sequence was the same as 2, except the sun was at a low-elevation position (5:30 to 6:30 p.m.).

Additional photographs were taken during each sequence whenever a maximum shadow/glare condition was thought to exist.

Data Recorded and Analysis Performed

The data recorded during each sequence of this test consisted of test sequence number, time of day, frame number, value of α, f-stop at 1/500 sec shutter speed, license plate state, and general comments. The film was processed to the negative stage and viewed to determine the conditions (sun position - vehicle heading angle combinations) for which each license plate was unreadable because of shadowing and/or glare problems.

4. Test 4 - Night Photography

Purpose

The purpose of this test was to determine the ability of each device's flash unit to provide suitable illumination for nighttime photography.

Fixed Parameters

Film: B&W of the type recommended by the manufacturer.

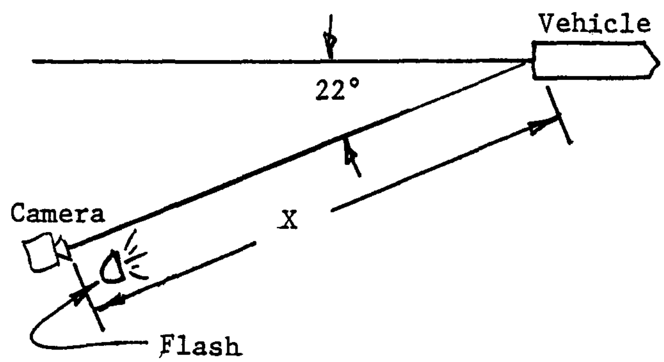
Environment: *Off the road, where controlled tests were possible.*

Vehicle: Stationary automobile with no unusual characteristics, but with an easy-to-see license plate. (Trucks were not considered.)

License Plate: Clean Missouri plate and a clean Kansas plate.

Lighting: Darkness, with no significant extra lighting such as streetlights.

Test Set Up



Test Procedures

Each device's flash unit was positioned near its associated camera, in accordance with the manufacturer's instructions. The vehicle lights were turned on and two exposures (one of each of the two state license plates) were taken at each of the following values of X: 30, 60, 90, 120, 135, and 150 ft.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: time of day, frame number, distance (X), license plate state, and general comments. The film was processed to the negative stage and viewed to determine the greatest range for complete readability of each of the two license plates under nighttime conditions.

5. Test 5 - Effect of Vehicle Speed on Photography and Accuracy of Speed Readings

Purpose

The purpose of this test was two-fold: (1) to determine the extent of blurring of the film image due to vehicle speed; and (2) to provide an estimate of the accuracy of the devices' speed readings.

Fixed Parameters

Film: B&W of the type recommended by the manufacturer.

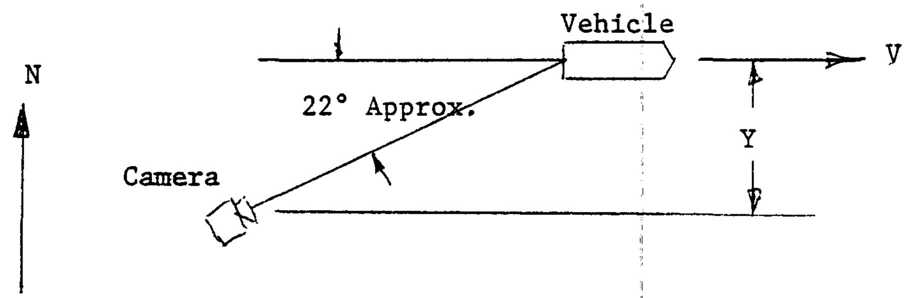
Environment: An unopened portion of interstate highway with 3-lanes in each direction.

Vehicle: Moving automobile.

License Plate: Clean Missouri plate.

Lighting: Midafternoon sun directly illuminating the license plate.

Test Set Up



Test Procedure

The devices were positioned on the right-hand shoulder of an unopened portion of an interstate highway. The units were stationed approximately 50 ft apart along a line parallel to and about 4 ft from the right lane (lane 1) edge marking. The test vehicle was driven past the devices at nominal speeds of 40, 50, and 60 mph at each of two values of Y: 10 and 35 ft, which corresponded to the approximate centerlines of lane 1 and lane 3, respectively. Between 2 and 5 replicate speed runs were made for each lane number-speed combination.

Initially, the test vehicle's speed was to be recorded using a fifth-wheel mounted on the far side of the vehicle (to avoid obscuring the license plate). Provision was made for the driver to record the vehicle's speed from the fifth-wheel readout when the vehicle passed through the beam of each test device. A malfunction of the fifth-wheel at the beginning of this test prevented its use. The test vehicle's speed was recorded, however, using an American-made radar (Digitar) aimed upstream to ensure that its beam would not interfere with the devices.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: frame number, lateral distance, Y, (lane number), the vehicle's speed as indicated by the speedometer, the Digitar speed reading, the devices' speed reading, and general comments. Two types of data analysis were performed. First, the film was processed to the negative stage and viewed to determine, for lanes 1 and 3, the maximum vehicle speed for which the license plate was completely readable. The second analysis involved computing the accuracy of the devices' speed readings. The mean and standard deviation of the devices' speed reading error (in mph) were determined relative to the Digitar speed readings for the nominal speeds of 40, 50, and 60 mph. The effects of lane number were not considered in the accuracy calculations.

6. Test 6 - Effect of Rain

Purpose

The purpose of this test was to determine the degradation of the film image caused by rain and vehicle splash and spray.

Fixed Parameters

Film:	B&W of the type recommended by the manufacturer.
Environment:	A divided highway with 2-lanes in each direction carrying light traffic.
Vehicle:	Any vehicles that happened to be on the road.
License Plate:	No restriction.
Lighting:	Daylight, cloudy, with light rain or very wet roadway.

Test Set Up

The devices were positioned on the right-hand shoulder of a multi-lane, divided highway.

Test Procedure

The devices were protected from direct exposure to rain, by using interior installations (Multanova and Traffipax systems) or by covering the units with plastic (Gatso and Truvelo systems). Raindrops were permitted to accumulate on the windshield of the Traffipax vehicle during the photographing. Between 7 and 27 photos of passing vehicles were taken with each system, providing a mixture of lane placements and vehicle types.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: frame number, whether or not the flash was used, vehicle type, and general comments. The film was processed to the negative stage and viewed to determine, for lanes 1 and 2, the number of readable license plates out of the population photographed.

7. Test 7 - Effect of Range on Radar Detection

Purpose

The purpose of this test was to determine the range limitation of the three radar units.

Fixed Parameters

System:	Radars only, without cameras.

Environment: An unopened portion of interstate highway with 3-lanes in each direction.

Vehicle: Moving automobile.

License Plate: Not applicable.

Lighting: Daylight.

Test Set Up

The three radar units, without cameras, were positioned on the right-hand shoulder of an unopened portion of an interstate highway. The radar units were stationed approximately 100 ft apart along a line parallel to and about 4 ft from the right lane edge marking.

Test Procedure

The test vehicle was driven past the devices at a nominal speed of 55 mph. One run was made at each of the following values of Y: 10, 22, 35, 40, 45, 50, 55, and 60 ft, until a missed (zero) reading was obtained. The lateral distance for the first missed reading was noted as Ym. Generally, three additional runs were made at Ym to confirm the misses. Three reruns were then made at Ym-5'. If one or more misses were noted at Ym-5', the series of three reruns were then made at additional reduced lateral spacings until no misses were noted for a given value of Y.

The test procedure was repeated twice for the Traffipax and three times for the Multanova to cover the available range selector switch settings of these systems.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: range setting, Y-value; and the test speeds recorded by the device, a fifth-wheel mounted on the test vehicle, and a Digitar radar aimed upstream to avoid interference with the devices. The recorded data were manually reviewed to determine the maximum lateral position for 100% and 50% detection under the various range settings.

8. Test 8 - Cosine Angle Effect

Purpose

The purpose of this test was to determine the magnitude of the "cosine error" effect for the three radar devices.

Fixed Parameters

System: Radars only, without cameras.

Environment: An unopened portion of interstate highway with 3-lanes in each direction.

Vehicle: Moving automobile.

License Plate: Not applicable.

Lighting: Daylight.

Test Set Up

The test set up was the same as that used in Test No. 7 (i.e., a normal system installation without cameras), except for the alignment angle of the radar. The radar units were purposely misaligned by 8 degrees. This produced an alignment angle of 30 degrees instead of the installation specification of 22 degrees.

Test Procedure

The test vehicle was driven past the devices at nominal speeds of 40, 45, 50, 55, 60, and 65 mph. Two replicate runs were made at each speed value. Three additional speed runs were made with the devices properly aligned to the manufacturers' specifications. In all the runs, the test vehicle was driven at a lateral distance (Y) of 22 ft from the devices, which corresponded to the approximate centerline of lane 2. Also, the radars were operated at their maximum range setting throughout the test.

Data Recorded and Analysis Performed

The data recorded during this test consisted of the alignment angle and the speed readings registered by the vehicle's speedometer, a fifth-wheel readout, and the radar devices. The mean speed measurement errors (expressed in percent) for both the 22 and 30 degree alignment angles were determined relative to the fifth-wheel speed measurements. The mean errors for the 22 degree alignment were computed using Test 5 data. The effect of the 8 degree misalignment angle was determined by subtracting the mean error at 22 degree from the mean error at 30 degree, taking into consideration the algebraic sign of the two mean errors.

9. Test 9 - Effect of Traffic Density

Purpose

The purpose of this test was to determine the degree to which the systems can distinguish between vehicles in moderate to heavy traffic volumes.

Fixed Parameters

System: Radars only, without cameras.

Environment: Several divided highways with 2-lanes in each direction, carrying one-way traffic volumes up to 3,500 vehicles per hour (vph).

Vehicle: Moving traffic.

License Plate: Not applicable.

Lighting: Daylight.

Test Set Up

The three radar units, without cameras, were positioned on the right-hand shoulder of the highways and set up in accordance with a normal system installation. The units were stationed approximately 50 ft apart along the shoulder.

Test Procedure

The alarm level of each radar unit was set to a low value so that essentially all vehicles detected should also have been detected as a violation. Also, the radars were operated at their maximum range setting throughout the test. The radars were operated, one at a time in a rotated sequence, for 3-min intervals. Aproximately 30, 3-min intervals of data recordings were obtained for each device, spanning a wide range of vehicle flow rates.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: beginning and ending time of each 3-min interval, a manual vehicle count, the device vehicle counts, the number of device alarms, and general comments. A series of linear regression analyses were performed of the data collected for each device. The percent of vehicles detected, D, was modeled as a linear function of vehicle flow rate, VPH (vehicle count per hour):

$$D = a_0 + b_0 \text{ VPH}.$$

Similarily, the percent of violations detected, V, was also modeled as a linear function of vehicle flow rate:

$$V = a_1 + b_1 \text{ VPH}.$$

The numerical values of the regression coefficients and the associated R^2 values for each device are presented in Table A-1. Here R^2 is a measure of the variability in the data explained by the respective regression model. This quantity can be interpreted as a measure of the efficacy of the model in explaining variations in D and V. If the model were perfect, R^2 would be equal to one, while if the model were totally useless, R^2 would be zero.

10. Test 10 - Effect of Vehicle Type

Purpose

The purpose of this test was to determine the extent to which different vehicle configurations may be missed by the three radar units.

TABLE A-1.-STATISTICAL QUANTITIES DESCRIBING PERCENT VEHICLES DETECTED AND PERCENT VIOLATIONS DETECTED BY THREE RADAR DEVICES

Statistical Quantity	Gatso Mini Radar	Multanova	Traffipax
a_0	100.0	100.0	95.5
b_0	-0.0150	-0.0178	-0.0191
R^2	0.77	0.87	0.91
a_1	85.7	100.0	94.8
b_1	-0.0133	-0.0178	-0.0189
R^2	0.65	0.87	0.90

Fixed Parameters

System:	Radars only, without cameras.
Environment:	A divided highway with 2-lanes in each direction carrying a moderate traffic volume, including trucks.
Vehicle:	Moving traffic.
License Plate:	Not applicable.
Lighting:	Daylight.

Test Set Up

Same as Test 9, except that only two of the radar units were tested on the same day. The two units were stationed approximately 100 ft apart along the shoulder to avoid potential electronic interference problems.

Test Procedure

The alarm value of each radar unit was set to a low value so that essentially all vehicles detected should also have been detected as a violation. Also, the radars were operated at their maximum range setting throughout the test. The two units tested on the same day were operated simultaneously.

During the testing, the one-way receding traffic was manually observed and data were collected for only isolated vehicles. Information was collected on 300 to 400 vehicles with each radar.

Data Recorded and Analysis Performed

The following data were recorded for each isolated vehicle of interest: lane number, vehicle type, vehicle detection (yes or no), violation counted (yes or no), and general comments. Vehicle type was stratified into 10 categories as follows:

1. Truck tractor with enclosed trailer or tanker, or loaded flat bed.
2. Truck tractor with flat bed (empty).
3. Truck tractor with flapping canvas.
4. Single unit truck or bus or RV.
5. Pickup or panel truck.
6. Pickup with flapping canvas or cover.
7. Sedan or station wagon.
8. Streamlined car (Corvette, Porsche, Toyota Celica, TR3, etc.).
9. Pickup or car with trailer.
10. Motorcycle.

A special, but simple, reporting form was developed for recording the above data.

A series of Chi-square tests were performed on the data collected for each device. To simplify the computations, the vehicle type data were compressed into two strata: "trucks" (categories 1 through 4) and "passenger vehicles" (categories 5 through 10). Statistical tests were made to determine if any association existed between missed vehicle detections and the two vehicle types for either lane, and if any association existed between missed vehicle detections and lane number for trucks and passenger vehicles. The same statistical tests were also performed using missed vehicle violations.

No significant relationship was found for the three radar devices between missed vehicle detections and vehicle types for either lane 1 or 2, with one exception. This occurred when the Multanova was operated at the long range setting. At this setting, the device missed more trucks than passenger vehicles in both lanes. Moreover, it missed more trucks in lane 1 than in lane 2.

The effects of vehicle type on missed vehicle violations was the same as found for missed vehicle detections.

11. Test 11 - Truvelo Detection Capability

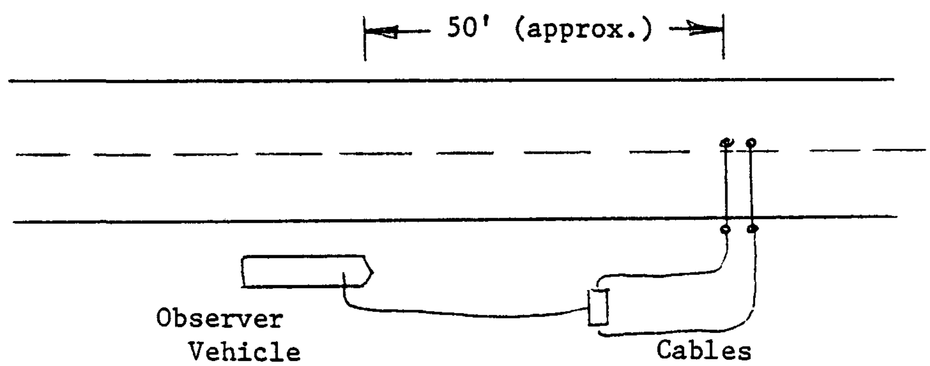
Purpose

The purpose of this test was to determine the detection capabilities of the Truvelo system when installed on a heavily traveled lane of a 55 mph facility.

Fixed Parameters

System:	Truvelo, installed on the near traffic lane only, and without camera, but operated in the automatic mode.
Environment:	A divided highway with 2-lanes in each direction, signed for 55 mph, and carrying moderate to heavy traffic volume including trucks.
Vehicle:	Moving traffic.
License Plate:	Not applicable.
Lighting:	Daylight.

Test Set Up



Test Procedure

Once the system was installed, two individuals positioned themselves in the observer vehicle, parked well off the traveled way, such that they could observe all vehicles crossing the roadway cables. Information was manually recorded in 3-min intervals on every vehicle crossing the roadway cables. The recording continued until over 1,000 vehicles crossed the cables.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: beginning and ending time of each 3-min interval, a manual count of vehicles crossing the roadway cables, and the number of vehicles not detected by the system. For each vehicle missed, the vehicle type was noted using the 10 categories of Test 10 along with any possible reason(s) or circumstance(s) that might explain the miss. The 3-min total counts of vehicles, and misses were accumulated to determine the number and percent of detections.

12. Test 12 - Detectability of Across-the-Road Radar

Purpose

The purpose of this test was to determine the detectability of the three radar devices using a commercially available radar detector.

Fixed Parameters

System: Radars only, without cameras.

Environment: Large parking lot.

Vehicle: Movable platform to support radar detector and associated power supply.

License Plate: Not applicable.

Lighting: Daylight.

Test Set Up

The three radar units, without cameras, were positioned, one at a time, at the origin of a radiation coordinate system layed out on the surface of a large parking lot. Each unit was set up in accordance with a normal system installation.

Test Procedure

The test procedure consisted of manually moving a commercially available radar detector (Fuzzbuster) throughout the electromagnetic radiation field produced by each radar device. The detector used for this test had a sensitivity or range control (an uncalibrated potentiometer). A linear scale was assigned to this control, ranging from a maximum to a minimum sensitivity. The goal of the manual searching was to determine, as a function of detector location relative to each device's transmitter, the setting at which the microwave radiation was just barely detectable.

Data Recorded and Analysis Performed

The data recorded during this test consisted of detector sensitivity setting for numerous coordinate values within the radiation field.

The electromagnetic radiation emitted by the Gatso and Traffipax with frequencies of 13.45 and 9.41 GHz, respectively, could not be detected by the standard Fuzzbuster radar detector, which was designed to be sensitive to the X-band (10.525 GHz). The X-band beam emitted by the Multanova was detected by the Fuzzbuster, but only under specific conditions. The Multanova results are shown in Figure A-1, as a contour map representing

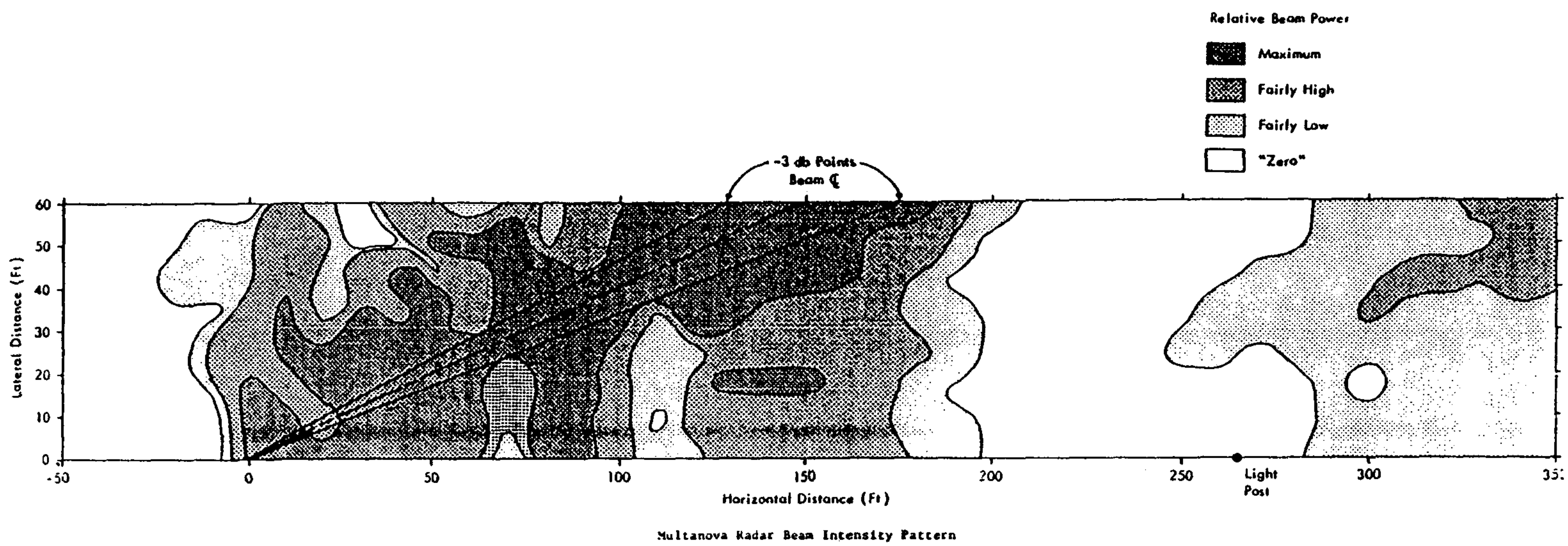


FIGURE A-1.-MULTANOVA RADAR BEAM INTENSITY PATTERN.

the relative beam intensity. Note that the beam was totally undetectable a very short distance upstream (left) of the transmitter. (The "zero" region is where no radar detection occurred, even with the detector set at maximum sensitivity/range.) The maximum power (i.e., beam detected with device set at minimum sensitivity) is essentially concentrated along the theoretical beam. The pattern irregularities are probably due to:

1. Inherent nonlinearities in the transmission device;
2. Reflections caused by the cabinet and its contents; and
3. Reflections from the pavement surface.

Additionally, the parking lot luminaire 265 ft from the transmitter could also have had some effect on the pattern. (The parking lot was otherwise devoid of obstructions.)

Finally, the Multanova beam would generally not be detected by receding traffic unless the Fuzzbuster was positioned facing the rear of the vehicle instead of its normal, forward facing position. The beam could be detected by approaching traffic, but the Multanova would not be monitoring this traffic.

13. Test 13 - Effect of Lane-Change Maneuvers on Detectability

Purpose

The purpose of this test was to determine the effect of a vehicle lane-change maneuver on detectability by the three radar devices.

Fixed Parameters

System:	Radars only, without cameras.
Environment:	An unopened portion of interstate highway with 3-lanes in each direction.
Vehicle:	Moving automobile.
License Plate:	Not applicable.
Lighting:	Daylight.

Test Set Up

The test set up was the same as that used in Test No. 7 (i.e., a normal system installation without cameras).

Test Procedure

The test vehicle was driven past each device at nominal speeds of 40 and 50 mph at each of two values of Y: 10 and 22 ft, which corresponded to the approximate centerlines of lane 1 and 2, respectively. As the vehicle entered the radar beam an abrupt lane change to either lane 2 or 1 was performed. The lane change maneuvers were characterized as left to right (towards the device) or right to left (away from the device). Generally, two replicate lane change maneuvers were made at each nominal speed and in each direction. The test vehicle's speed was recorded using a fifth-wheel.

Data Recorded and Analysis Performed

The data recorded during this test consisted of the direction of the lane change maneuvers (left to right or right to left); the vehicle's speed as indicated by the fifth-wheel; the vehicle's detection as indicated by the devices' speed reading; and general comments.

Two levels of data analysis were performed. First, the number of detections were counted. Secondly, the speed reading error (in percent) of each device was determined relative to the fifth-wheel measurement for each direction of lane change maneuver.

14. Test 14 - Effect of Braking

Purpose

The purpose of this test was to determine the effect of a vehicle braking maneuver on detectability by the three radar devices.

Fixed Parameters

Same as Test No. 13.

Test Set Up

Same as Test No. 13.

Test Procedure

Same as Test No. 13 except the test vehicle was driven past the devices at a nominal speed of 50 mph in lane 2. (A nominal speed of 40 mph was also used in the testing of the Multanova.) As the vehicle entered the radar beam an abrupt braking maneuver was performed. Six replicate braking maneuvers were conducted with the Gatso and Traffipax devices while eight replicate tests were conducted with the Multanova (four at each nominal speed). The test vehicle's speed was recorded using a fifth wheel.

Data Recorded and Analysis Performed

The data recorded during this test consisted of the fifth-wheel speed reading, the speed reading registered by the devices, an indication of vehicle detections (yes or no), and general comments.

The only analysis of the data conducted was to determine the number of detections registered by each device and possible reasons for missed detections.

15. Test 15 - Effect of Jammers on Radar Detection

Purpose

The purpose of this test was to determine if radar jammers could cause the three radar devices to produce false readings.

Fixed Parameters

System:	Radars only, without cameras.
Environment:	Large parking lot.
Vehicle:	Movable platform to support radar jammers and associated power supply.
License Plate:	Not applicable.
Lighting:	Daylight.

Test Set Up

Same as Test No. 12.

Test Procedure

The test procedure consisted of manually moving two radar jammers throughout the electromagnetic radiation field produced by each radar device. One of the jammers was built by engineers at the Federal Communication Commission (FCC) for in-house testing purposes. The unit was supposedly capable of producing false speed readings of either 25 or 50 mph using a transmitted electromagnetic radiation frequency of 10.525 GHz. The other jammer was commercially available under the code name "MS-1." This unit was supposedly capable of producing false speed readings of either 20, 28, 38, 54, or 81 mph, also using a transmitted electromagnetic radiation fequency of 10.525 GHz. The goal of the manual searching was to determine if false speed readings could be forced upon the three radar devices, and if so, from what point(s) within the radiation field.

The Digitar radar unit was also operated independently in the presence of the two jammers for comparison purposes.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: jammer used, radiation field coordinate values, transmitted false speed setting, device speed reading, Digitar speed reading, and general comments.

No false speed readings were recorded by any of the three radar devices when tested against the two radar jammers. The Digitar did respond to the two jammers, producing false speed readings close (within 1 to 3 mph) to the transmitted values of the MS-1, but widely variant from the transmitted values of the FCC unit.

16. Test 16 - Effect of Citizen Band Radio Transmission Interference

Purpose

The purpose of this test was to determine if citizen band (CB) radio transmission from near the three radar devices could cause interference with the detection capability of the devices.

Fixed Parameters

System: Radars only, without cameras.

Environment: A 2-way city street with 2-lanes in each direction carrying a light traffic volume, including trucks.

Vehicle: Moving traffic.

License Plate: Not applicable.

Lighting: Daylight.

Test Set Up

The three radar devices, without cameras, were positioned in the curb area of a 2-lane, 2-way city street and set up in accordance with a normal system installation.

Test Procedure

The alarm level of each radar unit was set to a low value so that essentially all vehicles detected should also have been detected as a violation. The radars were operated, one at a time. The test operator observed the device's detection capability while operating a 5-watt CB radio near the device. Three types of CB radio transmission were used: keying, whistling, and talking. Also, two transmission channels were used: 9 and 19. During the testing only the receeding traffic was observed and data were collected for isolated vehicles in both lanes.

Data Recorded and Analysis Performed

The data recorded during this test consisted of: CB channel, location of CB transmitter with respect to the radar device, type of CB transmission (keying, whistling, and talking), vehicle detection (yes or no), and general comments.

Citizen band radio transmission near the Gatso and Traffipax did not interfere with the detection capability of these devices. However, the CB transmission did interfere with the ability of the Multanova device to detect vehicles in lane 2 but not in lane 1. A 15% reduction in vehicle detections was noted for lane 2.

17. Test 17 - Effect of 161 Kv High Tension Line Interference

Purpose

The purpose of this test was to determine the effect upon vehicle detection capability of the three radar devices when operated near a 161 Kv high tension line.

Fixed Parameters

System:	Radars only, without cameras.
Environment:	A 2-way highway with 2-lines in each direction carrying a light traffic volume, including trucks. The 161 Kv high tension line ran parallel to the highway. The center line of the high tension line was located approximately 39 ft from the edge of the roadway.
Vehicle:	Moving traffic.
License Plate:	Not applicable.
Lighting:	Daylight.

Test Set Up

The three radar devices, without cameras, were set up in accordance with a normal system installation on the shoulder area of a highway. The units were operated one at a time.

Additional tests of the three radar devices were performed on a multi-lane divided highway in the absence of any overhead power lines. For these control tests, the devices were also set up in accordance with a normal system installation on the shoulder area of the highway.

Test Procedure

During both the high tension line and control tests, the alarm level of each radar unit was set to a low value so that essentially all vehicles detected should also have been detected as a violation. Also, the Multanova and Traffipax devices were operated at their short range setting throughout the tests.

During the testing, the receding traffic was manually observed and data were collected for only isolated vehicles. Information was collected on 180 to 330 vehicles with each radar during the high tension line tests and on 100 to 200 vehicles during the control tests.

Data Recorded and Analysis Performed

The types of data recorded and method of recording were the same as noted for Test No. 10 (Effect of Vehicle Type). The data recorded during Test No. 10 were pooled with the control data collected during Test No. 17 to increase the sample size.

A series of Chi-square tests were performed on the data recorded for each device. The vehicle type data were again compressed into the two strata used in the analysis of Test 10 data: trucks (categories 1 through 4) and passenger vehicles (categories 5 through 10). Statistical tests were made to determine if any association existed between missed vehicle detections and high tension line interference for the vehicle type-lane number combinations. The same statistical tests were also performed using missed vehicle violations.

Operating the Multanova and Traffipax near a 161 Kv high tension line had no significant effect upon the number of missed vehicle detections and missed speed violations observed for the two devices. These results were valid for all vehicle type-lane number combinations investigated. A significant interference effect, albeit limited, was observed for the operation of the Gatso. Significantly more passenger vehicles (12.4%) were missed (at a 95% confidence limit) in lane 2 when the device was operated in the presence of the high tension line.

18. Test 18 - Effects of Different Lenses and Projection Systems

Background for Test 18

Test No. 18 was not developed as part of the original engineering field test plan. Instead, it was formulated as a result of feedback received from the state police agencies during their initial trials with the ASE devices.

Our preliminary impression at the end of photographic portion of the engineering tests was that all four ASE systems may be marginal at consistently producing photographs with readable license plates. This was anticipated to some extent, because American plates have much smaller lettering than European plates.

During the early portion of the preliminary law enforcement agency tests several problems were identified regarding readability of the license plates. The problems were:

1. The year, state, and county identifiers on the license plates are much smaller lettering than the license number. These small numbers and letters were impossible to read. The police had to use the license plate format as the only clue to in-state or out-of-state status. Out-of-state license plates could not be completely identified unless the smaller lettered state designator could be read.

2. Many numbers or letters on the license plate were hard to read because of their similarity (i.e., M and W; N, H, and K; 5 and S; B, 8, and 3; I and 1; etc.).

3. License plates were increasingly more difficult to read as the vehicle was further away from the camera. Typically, license plates on vehicles in lane 1 (the closest lane) were relatively easy to read; mixed results were found for license plate readability for vehicles in lane 2; and few, if any, license plates for vehicles in lane 3 were readable.

4. Problem Number 3 was aggravated because the officers, possibly either from force of habit or for reasons of safety, parked farther off the road edge than recommended. It appeared, at least from a limited review of data, that many of the officers parked the vehicle as far over on the paved shoulders as possible. This resulted in the radar antenna and photographic unit being positioned at least 10 ft off the pavement edge, compared to the recommended 6 ft. Although 4 ft does not seem significant, when the photographic and radar beam angles are taken into account, this placed the violating vehicles roughly 18 ft further away from the camera, as measured along the camera axis. Since our engineering test data indicated that lane 2 vehicles are already positioned close to the limit of readability, another 18-ft move away from the camera can be critical.

All of the above problems are related to the image size of the license plate, which adversely affects the readability or precise identification of the origin and license number of the violating vehicle.

In an attempt to alleviate the above problems in the data reduction stages, a brief experiment was conducted using a higher intensity projection system and an increased projected image size. These tests were partially successful at improving the percentage of license plates totally readable. At this point, the only practical approach left was to try utilizing a longer camera lens to obtain larger images of the license plate on the film. The exposed film would then be viewed using several different projection systems. This approach was formulated as Test 18.

Purpose

The purpose of this test was to determine the usefulness of longer camera lens on the readability of license plates, and to determine the effects of using different projection systems.

Fixed Parameters

System:	The Truvelo device with its Robot camera and associated 75 mm lens, plus a Chinon CE-4 camera with 135 mm lens, power winder and remote triggering.
Film:	Black and white, Tri-X pan (ASA 400).
Environment:	A 4-lane, divided highway carrying moderately heavy traffic.
Vehicle:	A wide variation of vehicle types.
License Plate:	A wide variation of license plate formats.
Lighting:	Daylight.

Test Set Up

The Truvelo cables were installed in lane 1 (the right hand lane) of a 4-lane, divided highway carrying moderately heavy traffic. The Chinon and Robot cameras were placed on the right shoulder at several longitudinal and lateral distances from the cables, to duplicate conditions that would be seen at an equivalent lane 1 or lane 2 location with the 75 mm, 135 mm, and a simulated 200 mm telephoto lens. Lane 3 simulations were not possible because of the limited cable lengths supplied with the Truvelo system. The Truvelo device was used to trigger both the Chinon camera and the Robot camera with its associated 75 mm lens so that simultaneous photographs were taken of the sample vehicle for comparison.

Test Procedure

The following tests were conducted:

- Lane 1 - 75 mm lens and 135 mm lens photographing the same vehicles simultaneously.
- Lane 1 - 75 mm lens and a simulated 200 mm lens photographing the same vehicles simultaneously.
- Lane 2 - 75 mm lens and 135 mm lens photographing the same vehicles simultaneously.

Throughout the tests, vehicles were manually selected, by switching the Truvelo photographic system controls on or off, to provide a wide variation of vehicle types and license plates. We wanted to photograph as many out-of-state license plates as possible to get a feel for the effect of color and reflectivity variations on the readability of the license plates. Exposure was set manually for both cameras using a light meter reading.

Data Recorded and Analysis Performed

The data recorded during this test consisted of description of the vehicles, their license plates and speeds, and field notes. The film was processed to the negative stage, and all film was viewed to determine, for all lane number-lens length combinations, the number of readable license plates.

Three different projection systems were used for data reduction:

- 150 watt filmstrip projector (Scrollfilm, same as provided to the cooperating State Police).
- 500 watt filmstrip projector (Standard RR 750).
- 500 watt microfilm reader (3M "500" Reader Printer Projector).

During the lane 1 tests with the 75 mm and simulated 200 mm lenses, the film in the Robot camera did not engage the transport mechanism properly so no simultaneous photographs were taken to compare with those taken with the simulated 200 mm lens.

Figure A-2 shows, for lanes 1 and 2, the influence of camera lens length on the readability of license plates. Curves are presented for the percentage of license plates that were either totally readable or totally

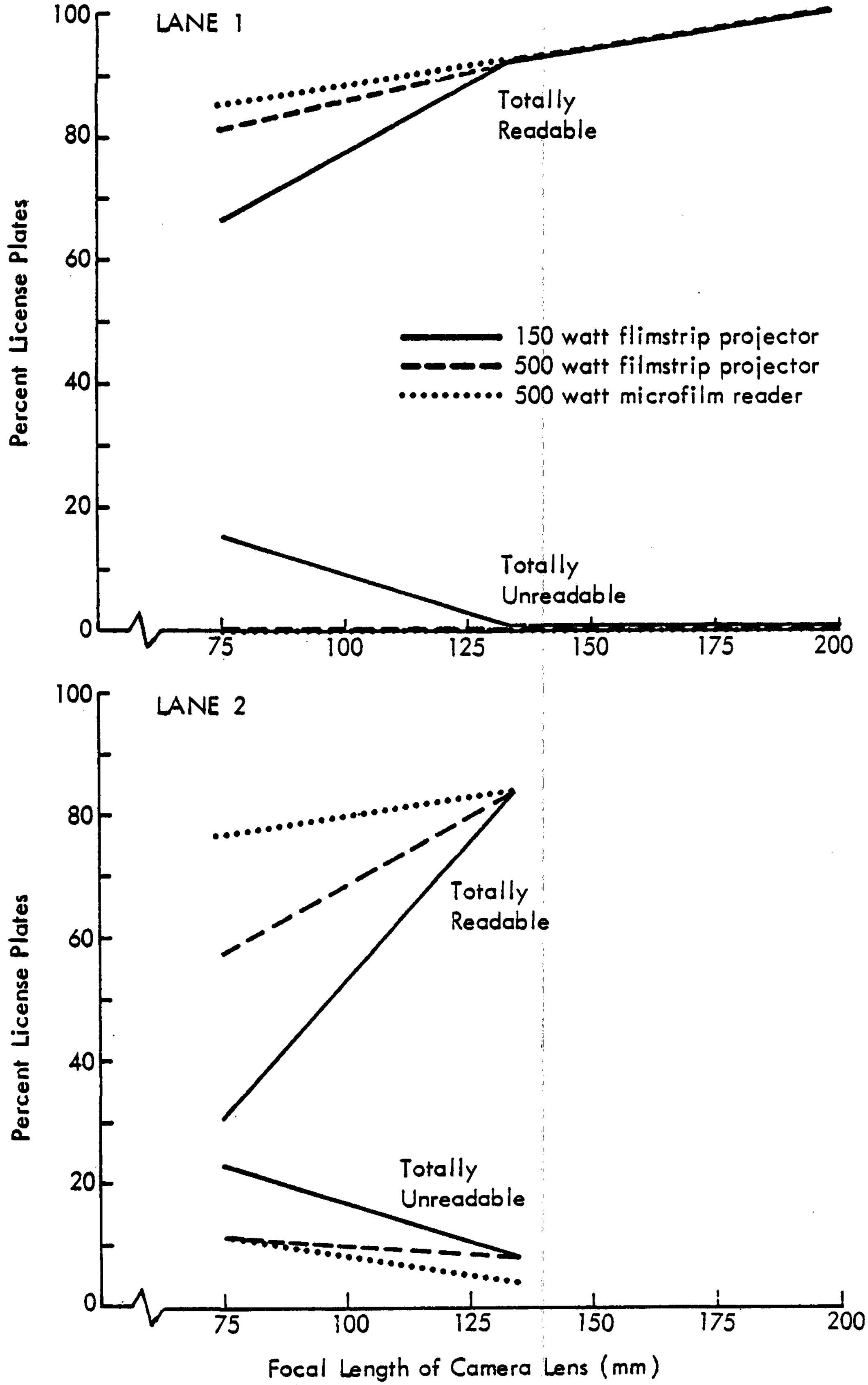


FIGURE A-2. INFLUENCE OF CAMERA LENS LENGTH AND PROJECTION SYSTEM ON THE READABILITY OF LICENSE PLATES.

unreadable. Also shown is the influence of the three different projection systems (basically, projection illumination) on the readability. For a given focal length lens, the difference between 100 and the sum of the two percentages shown for the same projection system defines the percentage of plates that were partially readable.

No attempt was made to perform a statistical analysis of the photographic test results. However, some general observations can be drawn from the data.

The general trends noted in the totally readable and totally unreadable curves for lane 1 are the same as those observed for lane 2. Increasing the length of the lens increases the readability of the license plates in both lanes 1 and 2. Using the 150 watt projector to view vehicles in lane 1, we obtained the results shown below:

Percentage of License Plates Totally Readable

	Lens		
	75	135	200
Lane 1	67	93	100
Lane 2	31	84	N.A.

The improvement in readability of license plates photographed with 135 mm and 200 mm lenses over those taken with the 75 mm lens was greater for lane 2 than for lane 1. Also, the incremental improvement between a 75 mm lens and a 135 mm lens was greater than the incremental improvement between the 135 mm and 200 mm lens.

The use of the higher wattage systems (500 watts versus 150 watts) increased the readability of the license plates photographed in either lane with a 75 mm lens. The use of the microfilm reader produced the highest percentage of totally readable license plates photographed in either lane with a 75 mm lens. The increase in readability over the 500 watt filmstrip projector was greatest for lane 2. The microfilm reader did not have any apparent effect on the total readability, compared to the other two projection systems, of license plates taken with either the 135 mm or simulated 200 mm lens. In fact, the 135 mm lens provided only a small advantage over the 75 mm lens in total readability when the microfilm reader was used.

For lane 1, a small percentage (15%) of the vehicle license plates photographed with the 75 mm lens and viewed with the 150 watt projection system were totally unreadable. The reasons for this were either the plates were too small, as is the case for motorcycle plates, or the plate was in a shadow. All of the plates photographed with the 75 mm lens were at least partially readable when viewed with the higher wattage projection systems. Further, there were no unreadable license plates in lane 2 when using the 135 mm or simulated 200 mm lens, regardless of the projection system.

For lane 2, a slightly higher percentage (23%) of the license plates photographed with the 75 mm lens and viewed with the 150 watt projection system were totally unreadable. Either the plates were too small (motorcycle), the plate image was blurred, or the plate was in a shadow or dirty. When the 75 mm photographs were viewed with the higher wattage projectors, the percentage of totally unreadable plates was reduced to 12%. When these same vehicles were photographed with the 135 mm lens, only two plates (both motorcycle) were totally unreadable when viewed with the 500 watt filmstrip projector. However, only one of the two motorcycle plates was totally unreadable when the microfilm reader was used. It is not known if the motorcycle plates in lane 2 would be totally or partially readable if photographed with a 200 mm lens.

In summary, the use of longer camera lens (longer than the standard 75 mm supplied with the device cameras) greatly enhances the readability of the vehicle license plates from the photographic negatives when viewed with a 150 watt or a 500 watt filmstrip projector. The improvement in readability of license plates photographed with 135 mm and 200 mm lenses over those taken with the 75 mm lens was greater for lane 2 than for lane 1. Also, the incremental improvement between a 75 mm lens and a 135 mm lens was greater than the incremental improvement between the 135 mm and 200 mm lens.

Increasing the length of the camera lens presents a potential risk of having the license plates of long vehicles (trucks, cars with trailers, etc.) fall out of the view of the camera. However, it is possible to minimize this risk to a greater or lesser extent (depending on the logic employed the particular detection system) by controlling the alignment of the camera system with respect to the detection system.

The 135 mm lens provides only a small advantage over the 75 mm lens in total readability when a 500 watt microfilm reader is used to view the photographic negatives.

19. Test 19 - Effects of Using Color Film on Readability of License Plates

Background for Test 19

Test No. 19 also was not developed as part of the original engineering field test plan. Instead, the test was formulated as a result of feedback received from the New Jersey State Police during the early portion of their preliminary law enforcement tests.

The New Jersey State Police identified another problem regarding readability of the license plates. Their review of five rolls of black and white film taken with the Gatso system revealed that many of the license plates appeared totally gray, even those in the first lane which should otherwise be readable. Well over half of the license plates appeared to be devoid of even the faintest outlines or images of numerals or letters. (The others appeared to be out of state or the old style New Jersey plates, and were more readable.) After isolating the problem to what appeared to be the new style of New Jersey plates, a simple test confirmed our hypothesis. A copy of the full color, FHWA 1980 License Plates brochure was photocopied (see Figure A-3) to simulate a black and white photograph. The new style New Jersey plates, which feature buff letters on a light blue background, have extremely poor contrast. Several other state license plates also appear to have similar contrast problems (e.g., 1977 Arizona, 1979 California, New Mexico, New York, Pennsylvania, and Wisconsin).

In an attempt to find a solution to this readability problem in the data reduction stages, it was decided to try photographing license plates using 400 ASA color slide film. Hopefully, the use of color film would eliminate the problem of reading license plates with extremely poor contrast. It was also decided to use a longer camera lens to obtain larger images of the license plate on the film. The exposed film would then be viewed using several projection systems. This approach was formulated as Test No. 19.

Purpose

The purpose of this test was to determine the effects of using color film on the readability of license plates, especially when the film was exposed using a longer camera lens and viewed using several different projection systems.

Fixed Parameters

System: The Truvelo device with its Robot camera and associated 75 mm lens, plus a Chinon CE-4 camera with 135 mm lens, power winder and remote triggering.

Film: 400 ASA color solid film.

Environment: A 4-lane, divided highway carrying moderately heavy traffic.

Vehicle: A wide variation of vehicle types.

License Plate: A wide variation of license plate formats.

Lighting: Daylight.

Test Set Up

The test set up was similar to that used for Test No. 18. The Truvelo cables were installed in lane 1 (the right-hand lane) of a 4-lane, divided highway carrying moderately heavy traffic. The Robot and Chinon cameras were placed on the right shoulder at a longitudinal and lateral distance from the cables, to duplicate conditions that would be seen at an equivalent lane 2 location with the 75 mm and 135 mm lenses.

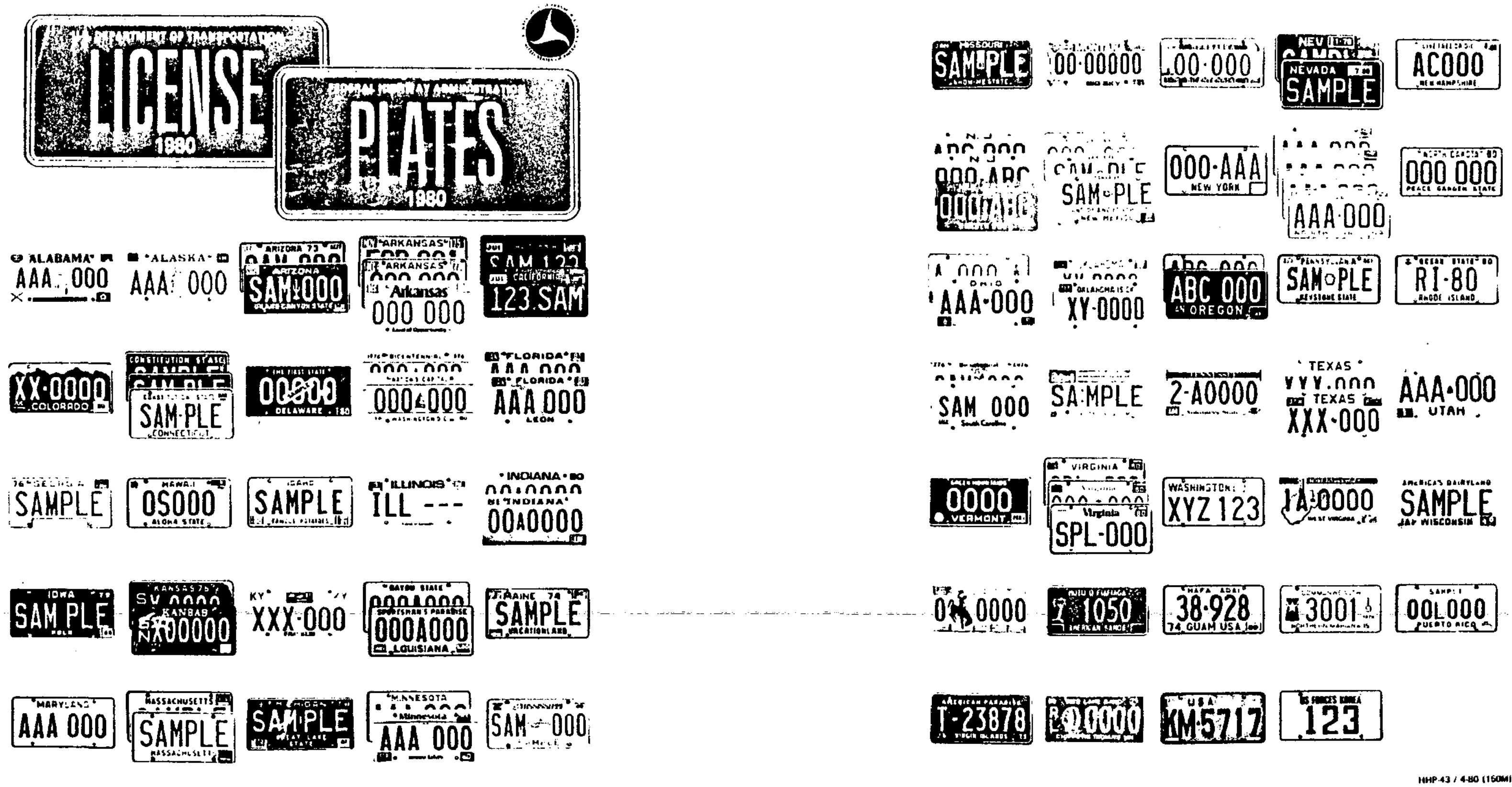


FIGURE A-3. SIMULATED BLACK AND WHITE PHOTOGRAPH OF FULL COLOR FHWA 1980 LICENSE PLATE BROCHURE.

Test Procedure

The Truvelo device was used to trigger both the Chinon and the Robot cameras so that simultaneous photographs were taken of the same vehicle for comparison. Throughout the test, vehicles were manually selected, by switching the Truvelo photographic system controls on or off, to provide a wide variation of vehicle types and license plates. We wanted to photograph as many out-of-state license plates as possible to get a feel for the effect of color and reflectivity variations on the readability of the license plates. Exposure was set manually for both cameras using a light meter reading.

Data Recorded and Analysis Performed

The data recorded during this test consisted of descriptions of the vehicles, their license plates and speeds, and field notes. The color film was processed in the normal manner and maintained in a strip form. The film was then viewed to determine, for each lens length, the number of readable license plates.

Three different projection systems were used for data reduction:

- 150 watt filmstrip projector (same as provided to the cooperating State Police).
- 500 watt filmstrip projector.
- 500 watt microfilm reader.

One problem occurred during the testing. The exposure setting for the 135 mm lens was incorrect for the color film, although no similar problem was found when black and white film was used. The color film requires more precise aperature settings, necessitating the use of a telephoto adapter on the light meter. As a result, the color film taken with the Chinon camera was improperly exposed (underexposed). The color film taken with the Robot camera, however, was properly exposed.

The percentage of license plates totally readable from the color film are shown below. Also shown are the influences of camera lens length and the three projection systems on the readability of the license plates.

PERCENTAGE OF LICENSE PLATES IN LANE 2
TOTALLY READABLE FROM COLOR FILM

Length of Lens and Projection System

75 mm Lens			135 mm Lens		
150 Watt Filmstrip Projector	500 Watt Filmstrip Projector	500 Watt Microfilm Reader	150 Watt Filmstrip Projector	500 Watt Filmstrip Projector	500 Watt Microfilm Reader
25%	61%	71%	7%	52%	82%

No attempt was made to perform a statistical analysis of the photographic test results. However, some general observations were drawn from the data.

It was difficult to detect any change in readability of license plates that could be attributed to the use of the longer lens length. The efficacy of using a 135 mm lens with color film was masked by the improper exposure of the film taken with the Chinon camera. Very few license plates photographed with the 135 mm lens were readable from the film when viewed with the 150 watt filmstrip. Also, a smaller than expected percentage of license plates were readable from the film when viewed with the 500 watt filmstrip projector. Both of these results could be attributed to the improper exposure.

The use of the higher wattage systems (500 watts versus 150 watts) increased the readability of the license plates photographed with either lens. The use of the microfilm reader produced the highest percentage of totally readable license plates. These are the same results as were noted when black and white film was used (see Test No. 18).

Other comparisons between using color and black and white film are as follows:

* When the 75 mm lens was used, no discernible improvement in readability of license plates was noted when color film was used. In fact, slightly higher percentages of license plates were totally readable from the black and white film (31% and 77%) when viewed with the 150 watt and 500 watt microfilm reader projection systems, respectively, than were readable from the color film (25% and 71%).

* The need for precise exposure settings adversely affects the desirability of using color film in conjunction with a lens longer than 75 mm.

* The use of color film enhances the positive identification of the state origin of the license plate and improves the readability of some license plates with poor color contrast.

APPENDIX B

RATING METHODOLOGY AND RESULTS

A rating methodology was developed to help generate estimates of the utility and cost effectiveness of different technological advancements for the deterrence of speeding when applied or implemented according to various strategies. As such, the methodology was designed to assist in the selection of those advancements with the greatest potential utility for successful use under given conditions. In this report, the methodology is used for the purpose of comparing the selected ASE devices and enforcement strategies. Section 1 of this Appendix provides an overview of the rating methodology developed. Section 2 discusses the various types of computed scores along with their interpretation. Section 3 describes the procedure used to assign the factor ratings to the technological advancements and the criteria followed in determining the confidence or reliability rating for each factor. The factors and factor weights used in the ratings are discussed in Section 4. Finally, Section 5 presents the numerical results of applying the rating methodology to various combinations of technological advancements and deployment strategies.

1. Overview of rating methodology: An ideal assessment of technological advancements would be based on actual implementation experience in the U.S. under various deployment strategies. However, almost all the advancements of primary interest in the study have never been used in the U.S.* Thus, it is not possible to determine quantitative measures of the immediate and long-term effects of these types of devices on the reduction of speeding and speed-related accidents. It is feasible, however, to determine rankings of the technological advancements relative to one another using a combination of quantitative and qualitative information placed in a quantitative framework. The rankings reported herein are based on: (1) data provided by the manufacturers; (2) information gained from personal contacts with European law enforcement users of the equipment; (3) results reported in the literature; (4) data recorded during the engineering field tests of the selected devices; (5) experience gained by the three state police agencies in trials with the selected ASE devices; and (6) the professional judgment of the project staff.

2. Category scores: The rating methodology consists of three basic categories of assessment: technical effectiveness, acceptability, and cost implications. The technical effectiveness category concerns the ability of the device to detect speeding motorists precisely, reliabily, productively and to be compatible with its operating environment. The acceptability category concerns how well the device is accepted by users, prosecutors and violators alike. The cost category reflects both the initial and operating costs for using the device.

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* An exception to this is the American-made version of the Orbis III device, which was used briefly in the U.S. This device was implemented only on a limited basis and is no longer in use.

Each of the three rating categories receives two "scores." One score is the best estimate of the degree to which, or probability that, the category has potential utility or is favorable. A zero score, at one extreme, would indicate no possibility of having utility; a one would indicate the highest possibility. In the case of costs, a high score would indicate low cost, and vice-versa. The second of the two scores incorporated the relative confidence in the first score. Devices that have been used in the field and about which data have been collected can be assessed much more confidently than advances that have only been considered conceptually. This second score also ranges from 0 to 1. Each category thus has two final scores expressed in the form:

W_i = probability of potential utility for category i (the unadjusted category score),

W_i^* = W_i times the relative confidence (the adjusted category score),

$W_e = W_1 W_2$ or

$W_e^* = W_1 W_2^*$,

which are relative scores of the overall practical or operational effectiveness. These scores combine the technical and acceptability aspects.

Another combined form of interest is:

$W = W_1 W_2 W_3$ or

$W^* = W_1 W_2 W_3^*$,

which can be regarded as relative scores of cost-effectiveness, because W_3 is inversely related to cost.

Ideally, the combined scores can be simply rank-ordered and the top-rated advances selected as having the most promise for use in U.S. speed enforcement. In practice, however, tradeoffs and compromises will probably be required because no device is perfect on all (or any) counts, so recourse will probably have to be made to using a judgment weighting between the three basic categories. Since there appears to be no strong basis at this point to make any of the three categories more important than any other, each category is weighted equally in these scores.

3. Factor ratings: The category scores were determined by a process involving a number of factors. The technical effectiveness category contains 10 factors, the acceptability category contains 4 factors, and the cost implications category contains 5 factors, all of which are identified and discussed below. Each factor was assigned a rating between 0 and 1. The highest rating, 1, was assigned when the factor did not limit the utility of the advancement in any way. Ratings less than 1 were assigned to factors that restricted the utility of an advancement to some extent, with smaller ratings indicating greater restrictions.

Each unadjusted category score, W_i, was obtained as a weighted average of the factor ratings w_i, for an advancement/deployment strategy combination. Each factor was given a weight between 0.01 and 1.0, depending on it relative importance in the category. A weighted average is calculated as:

$$W = \frac{f_1w_1 + f_2w_2 + f_3w_3 + \ . \ . \ .}{w_1 + w_2 + w_3 + \ . \ . \ .}$$

The sum of all factor weights in a given category is 1.0. The category scores are thus on the same 0 to 1.0 scale as the factor ratings.

The adjusted category score, W_i^*, indicates the relative confidence of the individual factor ratings and of the category scores. A confidence or reliability rating for each factor was selected on a scale of 0.1 to 1.0. The highest reliability rating, 1.0, was reserved for factor ratings assigned on the basis of widespread experience with the technology over an extended period by law enforcement agencies. The maximum reliability rating for technology tested in the field by manufacturers and others (but not law enforcement agencies) was 0.7 and the maximum reliability rating for laboratory or analytical evidence was 0.4. Factor ratings based solely on judgment received the lowest reliability rating (down to 0.1). Intermediate values were assigned when, for example, there was only limited law enforcement agency experience.

An adjusted category score was computed for each of the three categories. The weighted factor rating for each factor in a category was multiplied by its respective reliability rating. The sum of these products, which is on a scale of 0 to 1.0, was recorded as the adjusted category score. Thus, for example,

$$W = \frac{f_1w_1r_1 + f_2w_2r_2 + f_3w_3r_3 + . \ . \ .}{w_1 + w_2 + w_3 + \ . \ . \ .}$$

where the r's are the reliability ratings.

The adjusted category score will generally be less than the unadjusted category score, the difference between them being a measure of the uncertainty about the technology and its application. This difference may be reduced through further experimentation and field experience.

4. Factors and weights: Table B-1 identifies the factors included in each of the three categories along with the respective factor weights used in the ratings.

The technical effectiveness category contains 10 factors that bear on the usefulness of the technological advancement for the deterrence of speeding. An important factor in this category is the productivity of the device in terms of fraction of speeders apprehended (Factor 1). This factor is assigned the greatest weight in the category. Three related assessments of how well the device works in the field are the capability of the device to detect speeding; the accuracy of the speed measurement; and the ability

TABLE B-1.-FACTORS AND FACTOR WEIGHTS FOR RATING TECHNOLOGICAL ADVANCEMENTS FOR THE DETERRENCE OF SPEEDING

Factor	Factor Weight
TECHNICAL EFFECTIVENESS	
1. Productivity of system in terms of fraction of speeders apprehended/notified	0.15
2. Speed detection capability	0.12
3. Accuracy of speed determination	0.12
4. Ability to identify specific vehicle	0.12
5. Device reliability	0.10
6. Presentation and preservation of speeding evidence	0.10
7. Ability of device to counteract motorist evasion	0.08
8. Traffic safety compatibility	0.08
9. Traffic flow compatibility	0.08
10. Environmental (weather) compatibility	0.05
	1.00
ACCEPTABILITY	
1. Legal acceptance	0.25
2. Judicial acceptance	0.25
3. Police acceptance	0.25
4. Public acceptance	0.25
	1.00
COST IMPLICATIONS	
1. Capitol equipment cost	0.25
2. Installation cost	0.25
3. Maintenance/repair cost	0.20
4. Operation cost other than manpower	0.15
5. Manpower operation cost	0.15
	1.00

of the device to identify a specific vehicle (Factors 2 through 4, weight 0.12 each). The reliability of the device (Factor 5) and the ability of the device to present and preserve evidence (Factor 6) are also included, each with a weight of 0.10. Other considerations addressed are the device's relative immunity from motorist counteractions (Factor 7); its ability to be compatible with the safety requirements for traffic operations on the highway (Factor 8); and its ability to be used in all traffic and weather situations (Factors 9 and 10). Factors 7 through 9 are each assigned a weight of 0.08 while Factor 10, a lesser consideration, is assigned a weight of 0.05. Factors 8 through 10 describe the compatibility of the device with its operating environment. Acceptable devices should not have side effects that might initiate conflicts or otherwise endanger motorists and the enforcing officer.

The acceptability category contains four factors that assess the legal, judicial, police, and public acceptance of the device. All four factors are assigned equal weight.

The cost category contains 5 factors. These account for the purchase and installation costs of the device (Factor 1 and 2); the maintenance/repair costs (Factor 3); the operational costs (excluding manpower) (Factor 4); and the operational manpower costs (Factor 5). The greatest factor weights (0.25) are assigned to the equipment purchase and installation cost factors. The maintenance/repair cost factor has a slightly smaller weight of 0.20. The combined manpower operating cost (both field and office support) and the subsidiary operating cost (power, supplies, etc.) have a total weight of 0.30.

In the cost category, each rating is determined using the reciprocal of the annualized cost. Thus, fixed costs such as the capital equipment and installation costs are prorated over the life of the device. Finally, the reciprocal costs are normalized. The normalization used was such that a cost of $2,000/yr or less was given a factor rating of 1.0.

5. Application of the rating methodology: The rating methodology was applied to several combinations of technological advancements and deployment strategies. The technologies rated were the following:

- American stationary radar;
- Gatso Mini Radar MK4;
- Multanova 4FA;
- Traffipax IV/R; and
- Truvelo Model 4.

Five deployment strategies were considered:

- Manned by single officer, who pursues and stops suspected violators (applied only with the American radar);
- Manned by single officer, without camera, and with a downstream, three-man stop team;
- Same as above except a camera is also used;
- Manned by a single officer, in fully automatic mode, without stopping violators; and
- Fully automatic, unmanned operation (applies only to the Gatso and the Multanova 4F devices).

All of the technologies and strategies were assumed to be applied to the same traffic scenario. It was assumed that speed enforcement is being carried out on a rural 4-lane divided highway with a 55 mph speed limit. It was assumed that the traffic volume was 1,200 vehicles per hour one way, which means that the traffic is fairly heavy, yet most drivers are unimpeded by other vehicles most of the time. It is relatively free flow with Level of Service A (by traffic engineering definitions) but approaching Level of Service B. This flow rate is approximately 30% of the capacity of the highway. It was further assumed that 10% of the vehicles would exceed 59 mph, the threshold being used for enforcement purposes. This assumption is not unrealistic based on Federal Highway Administration data.

It was furthermore assumed, for purposes of applying the ratings uniformly, that with the exception of the last deployment strategy (unmanned, fully automatic operation) the percentage of speeding stated above (10 %) was not influenced by the enforcement efforts per se. In other words, the effectiveness of radar detectors, CB radios, etc., was either ignored or assumed to affect all ratings equally. An exception was made with the fully automatic system because such systems are usually in place for long periods of time and become quite well known to local inhabitants. It was therefore assumed that speeding was only 30% as prevalent near these permanent installations, for the purposes of the ratings.

The numerical results of the ratings are given in Tables B-2 through B-17. The following paragraphs discuss some of the rationale behind the assignment of numerical values to each of the factors.

The productivity factor is a measure of the degree to which speeders who have been detected and identified can be apprehended and/or notified of the fact of the violation. In the case of the manned systems where detected violators are stopped on the scene, it was assumed that an average processing time of 18 minutes per officer was required (20 minutes if the same officer also operated the radar). This time, in effect, is perhaps the most limiting factor for such deployment strategies, and systems using such strategies therefore received fairly low productivity ratings. Systems using photography received less than perfect ratings because of such considerations as out-of-state motorists and lack of accurate vehicle registration data, which decrease the ability to notify all detected violators.

The speed detection capability factor is just that--it is the ability of the system to determine whether or not an isolated vehicle is speeding. The systems all have less than perfect ratings for a number of reasons. The equipment may not always be turned on and operational (e.g., it may be in the process of having its film changed or being calibrated); the officer manning the equipment must take notice of the reading; the system must not reject the Doppler frequency because of transients or electrical noise (which the cross-the-road systems, because of their conservative design, will do on occasion); etc.

The accuracy factor for all of the systems is rated very highly, because they are all inherently very accurate. However, they can be operated improperly on occasion, leading to some loss in accuracy. In particular, the need to properly align the sensing devices with the traffic is important. This alignment is likely to be a slightly bigger problem using the first of the deployment strategies, where the officer must reposition his vehicle and his radar equipment after every pursuit and stop (despite manufacturer efforts to simply the alignment process).

TABLE B-2.-RATING SYSTEM APPLIED TO AN AMERICAN DOWN-THE-ROAD RADAR USED BY A SINGLE OFFICER TO STOP SPEEDING MOTORISTS

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/notified.	0.025	0.15	0.004	1.0	0.004
2.	Speed detection capability.	0.7	0.12	0.08	1.0	0.08
3.	Accuracy of speed determination.	0.8	0.12	0.10	1.0	0.10
4.	Ability to identify specific vehicle.	0.5	0.12	0.06	0.9	0.05
5.	Device reliability.	0.95	0.10	0.10	1.0	0.10
6.	Presentation and preservation of speeding evidence.	0.5	0.10	0.05	1.0	0.05
7.	Ability of device to counteract motorist evasion.	0.6	0.08	0.05	0.9	0.04
8.	Traffic safety compatibility.	0.5	0.08	0.04	0.8	0.03
9.	Traffic flow compatibility.	0.3	0.08	0.02	1.0	0.02
10.	Environmental (weather) compatibility.	0.6	0.05	0.03	0.8	0.02
			1.00	0.53		0.49
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	1.0	0.25
2.	Judicial acceptance.	0.9	0.25	0.23	0.9	0.20
3.	Police acceptance.	1.0	0.25	0.25	1.0	0.25
4.	Public acceptance.	0.8	0.25	0.20	0.9	0.18
			1.00	0.93		0.88
	Category - Cost Implications					
1.	Capitol equipment cost.	1.0	0.25	0.25	1.0	0.25
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	1.0	0.15	0.15	1.0	0.15
5.	Manpower operation cost.	0.17	0.15	0.03	1.0	0.03
			1.00	0.88		0.84

TABLE B-3.-RATING SYSTEM APPLIED TO AN AMERICAN DOWN-THE-ROAD RADAR USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.1	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.7	0.12	0.08	1.0	0.08
3.	Accuracy of speed determination.	0.85	0.12	0.10	1.0	0.10
4.	Ability to identify specific vehicle.	0.5	0.12	0.06	0.9	0.05
5.	Device reliability.	0.95	0.10	0.10	1.0	0.10
6.	Presentation and preservation of speeding evidence.	0.05	0.10	0.05	1.0	0.05
7.	Ability of device to counteract motorist evasion.	0.6	0.08	0.05	0.9	0.04
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.3	0.08	0.02	1.0	0.02
10.	Environmental (weather) compatibility.	0.6	0.05	0.03	0.8	0.02
			1.00	0.57		0.51
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.9	0.25	0.23	0.7	0.16
3.	Police acceptance.	0.9	0.25	0.23	0.8	0.18
4.	Public acceptance.	0.7	0.25	0.18	0.8	0.14
			1.00	0.89		0.68
	Category - Cost Implications					
1.	Capitol equipment cost.	1.0	0.25	0.25	1.0	0.25
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	1.0	0.15	0.15	0.8	0.12
5.	Manpower operation cost.	0.04	0.15	0.006	1.0	0.006
			1.00	0.86		0.79

TABLE B-4.-RATING SYSTEM APPLIED TO A CAMERALESS GATSO MINI RADAR MK4 USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.1	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.7	0.12	0.08	1.0	0.08
3.	Accuracy of speed determination.	0.98	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.75	0.12	0.09	1.0	0.09
5.	Device reliability.	0.7	0.10	0.07	1.0	0.07
6.	Presentation and preservation of speeding evidence.	0.5	0.10	0.05	1.0	0.05
7.	Ability of device to counteract motorist evasion.	0.9	0.08	0.07	0.9	0.06
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	1.0	0.05
10.	Environmental (weather) compatibility.	0.7	0.05	0.04	1.0	0.04
			1.00	0.65		0.61
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.8	0.25	0.20	0.6	0.12
3.	Police acceptance.	0.7	0.25	0.18	0.9	0.16
4.	Public acceptance.	0.7	0.25	0.18	0.6	0.11
			1.00	0.81		0.59
	Category - Cost Implications					
1.	Capitol equipment cost.	1.0	0.25	0.25	1.0	0.25
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	1.0	0.15	0.15	1.0	0.15
5.	Manpower operation cost.	0.04	0.15	0.006	1.0	0.006
			1.00	0.86		0.82

TABLE B-5.-RATING SYSTEM APPLIED TO A CAMERALESS MULTANOVA 4FA USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.1	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.79	0.12	0.09	1.0	0.09
3.	Accuracy of speed determination.	1.0	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.75	0.12	0.09	1.0	0.09
5.	Device reliability.	0.95	0.10	0.10	1.0	0.10
6.	Presentation and preservation of speeding evidence.	0.5	0.10	0.05	1.0	0.05
7.	Ability of device to counteract motorist evasion.	0.8	0.08	0.06	0.9	0.06
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	1.0	0.05
10.	Environmental (weather) compatibility.	0.8	0.05	0.04	1.0	0.03
			1.00	0.68		0.64
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.8	0.25	0.20	0.6	0.12
3.	Police acceptance.	0.8	0.25	0.20	0.9	0.18
4.	Public acceptance.	0.7	0.25	0.18	0.6	0.11
			1.00	0.83		0.61
	Category - Cost Implications					
1.	Capitol equipment cost.	0.50	0.25	0.13	1.0	0.03
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	1.0	0.15	0.12	1.0	0.12
5.	Manpower operation cost.	0.04	0.15	0.01	1.0	0.01
			1.00	0.71		0.67

TABLE B-6.-RATING SYSTEM APPLIED TO A CAMERALESS TRAFFIPAX IV/R USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.1	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.73	0.12	0.09	1.0	0.09
3.	Accuracy of speed determination.	0.99	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.7	0.12	0.08	1.0	0.08
5.	Device reliability.	0.95	0.10	0.10	1.0	0.10
6.	Presentation and preservation of speeding evidence.	0.5	0.10	0.05	1.0	0.05
7.	Ability of device to counteract motorist evasion.	0.9	0.08	0.07	0.9	0.06
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	1.0	0..05
10.	Environmental (weather) compatibility.	0.7	0.05	0.04	1.0	0.04
			1.00	0.68		0.64
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.8	0.25	0.20	0.6	0.12
3.	Police acceptance.	0.75	0.25	0.19	0.9	0.17
4.	Public acceptance.	0.7	0.25	0.18	0.6	0.11
			1.00	0.82		0.66
	Category - Cost Implications					
1.	Capitol equipment cost.	0.82	0.25	0.21	1.0	0.21
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	1.0	0.15	0.15	1.0	0.15
5.	Manpower operation cost.	0.04	0.15	0.006	1.0	0.006
			1.00	0.82		0.78

TABLE B-7.-RATING SYSTEM APPLIED TO A CAMERALESS TRUVELO MODEL 4 USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.1	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.99	0.12	0.12	1.0	0.12
3.	Accuracy of speed determination.	0.99	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.8	0.12	0.10	0.9	0.09
5.	Device reliability.	0.9	0.10	0.09	1.0	0.09
6.	Presentation and preservation of speeding evidence.	0.6	0.10	0.06	1.0	0.06
7.	Ability of device to counteract motorist evasion.	1.0	0.08	0.08	0.9	0.07
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	1.0	0.05
10.	Environmental (weather) compatibility.	0.7	0.05	0.04	1.0	0.04
			1.00	0.74		0.69
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.9	0.25	0.23	0.8	0.18
3.	Police acceptance.	0.5	0.25	0.13	0.8	0.10
4.	Public acceptance.	0.9	0.25	0.23	0.6	0.14
			1.00	0.84		0.62
	Category - Cost Implications					
1.	Capitol equipment cost.	1.0	0.25	0.25	1.0	0.25
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	1.0	0.15	0.15	1.0	0.15
5.	Manpower operation cost.	0.04	0.15	0.006	1.0	0.006
			1.00	0.86		0.82

TABLE B-8.-RATING SYSTEM APPLIED TO A GATSO MINI RADAR MK4 WITH CAMERA USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.1	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.7	0.12	0.08	1.0	0.08
3.	Accuracy of speed determination.	0.98	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.75	0.12	0.09	1.0	0.09
5.	Device reliability.	0.7	0.10	0.07	1.0	0.07
6.	Presentation and preservation of speeding evidence.	0.7	0.10	0.07	1.0	0.07
7.	Ability of device to counteract motorist evasion.	0.9	0.08	0.07	0.9	0.06
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	1.0	0.05
10.	Environmental (weather) compatibility.	0.7	0.05	0.04	1.0	0.04
			1.00	0.67		0.63
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.9	0.25	0.23	0.5	0.11
3.	Police acceptance.	0.7	0.25	0.18	0.9	0.16
4.	Public acceptance.	0.7	0.25	0.18	0.4	0.07
			1.00	0.84		0.54
	Category - Cost Implications					
1.	Capitol equipment cost.	0.51	0.25	0.13	1.0	0.13
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	0.21	0.15	0.03	1.0	0.03
5.	Manpower operation cost.	0.03	0.15	0.005	0.6	0.003
			1.00	0.62		0.57

TABLE B-9.-RATING SYSTEM APPLIED TO A MULTANOVA 4FA WITH CAMERA USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/notified.	0.1	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.79	0.12	0.09	1.0	0.09
3.	Accuracy of speed determination.	1.0	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.75	0.12	0.09	1.0	0.09
5.	Device reliability.	0.9	0.10	0.09	1.0	0.09
6.	Presentation and preservation of speeding evidence.	0.6	0.10	0.06	1.0	0.06
7.	Ability of device to counteract motorist evasion.	0.8	0.08	0.06	0.9	0.06
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	1.0	0.05
10.	Environmental (weather) compatibility.	0.8	0.05	0.04	1.0	0.04
			1.00	0.68		0.65
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.9	0.25	0.23	0.5	0.11
3.	Police acceptance.	0.8	0.25	0.20	0.9	0.18
4.	Public acceptance.	0.7	0.25	0.18	0.4	0.07
			1.00	0.86		0.56
	Category - Cost Implications					
1.	Capitol equipment cost.	0.28	0.25	0.07	1.0	0.07
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	1.0	0.15	0.05	1.0	0.05
5.	Manpower operation cost.	0.03	0.15	0.005	0.6	0.003
			1.00	0.58		0.53

TABLE B-10.-RATING SYSTEM APPLIED TO A TRAFFIPAX IV/R WITH CAMERA USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/notified.	0.10	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.73	0.12	0.09	1.0	0.09
3.	Accuracy of speed determination.	0.99	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.7	0.12	0.08	1.0	0.08
5.	Device reliability.	0.9	0.10	0.09	1.0	0.09
6.	Presentation and preservation of speeding evidence.	0.7	0.10	0.07	1.0	0.07
7.	Ability of device to counteract motorist evasion.	0.9	0.08	0.07	0.9	0.06
8.	Traffic safety compatibility.	0.7	0.08	0.06	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	1.0	0.05
10.	Environmental (weather) compatibility	0.7	0.05	0.04	1.0	0.04
			1.00	0.69		0.65
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.9	0.25	0.23	0.5	0.11
3.	Police acceptance.	0.75	0.25	0.19	0.9	0.17
4.	Public acceptance.	0.7	0.25	0.18	0.4	0.07
			1.00	0.85		0.55
	Category - Cost Implications					
1.	Capitol equipment cost.	0.43	0.25	0.11	1.0	0.11
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	0.21	0.15	0.03	1.0	0.03
5.	Manpower operation cost.	0.03	0.15	0.005	0.6	0.003
			1.00	0.60		0.55

TABLE B-11.-RATING SYSTEM APPLIED TO A TRUVELO MODEL 4 WITH CAMERA USED BY AN OFFICER IN COMBINATION WITH A DOWNSTREAM, THREE-OFFICER STOP TEAM

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.10	0.15	0.02	0.9	0.01
2.	Speed detection capability.	0.99	0.12	0.12	1.0	0.12
3.	Accuracy of speed determination.	0.99	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.8	0.12	0.10	0.9	0.09
5.	Device reliability.	0.85	0.10	0.09	1.0	0.09
6.	Presentation and preservation of speeding evidence.	0.8	0.10	0.08	0.9	0.07
7.	Ability of device to counteract motorist evasion.	1.0	0.08	0.08	0.9	0.07
8.	Traffic safety compatibility.	0.65	0.08	0.05	0.8	0.04
9.	Traffic flow compatibility.	0.6	0.08	0.05	0.9	0.04
10.	Environmental (weather) compatibility	0.7	0.05	0.04	0.8	0.03
			1.00	0.75		0.68
	Category - Acceptability					
1.	Legal acceptance.	1.0	0.25	0.25	0.8	0.20
2.	Judicial acceptance.	0.95	0.25	0.24	0.7	0.17
3.	Police acceptance.	0.5	0.25	0.13	0.8	0.10
4.	Public acceptance.	0.9	0.25	0.23	0.4	0.09
			1.00	0.85		0.56
	Category - Cost Implications					
1.	Capitol equipment cost.	1.0	0.25	0.25	1.0	0.25
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	0.29	0.15	0.04	1.0	0.04
5.	Manpower operation cost.	0.03	0.15	0.005	0.6	0.003
			1.00	0.75		0.70

TABLE B-12.-RATING SYSTEM APPLIED TO A GATSO MINI RADAR MK4 WITH CAMERA USED BY A SINGLE OFFICER WHO OBSERVES BUT DOES NOT STOP SPEEDING MOTORISTS

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/notified.	0.47	0.15	0.07	0.9	0.06
2.	Speed detection capability.	0.7	0.12	0.08	0.9	0.08
3.	Accuracy of speed determination.	0.98	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.9	0.12	0.11	1.0	0.11
5.	Device reliability.	0.7	0.10	0.07	1.0	0.07
6.	Presentation and preservation of speeding evidence.	0.75	0.10	0.08	0.9	0.07
7.	Ability of device to counteract motorist evasion.	0.75	0.08	0.06	0.8	0.05
8.	Traffic safety compatibility.	0.85	0.08	0.07	0.9	0.06
9.	Traffic flow compatibility.	0.7	0.08	0.06	0.9	0.05
10.	Environmental (weather) compatibility	0.7	0.05	0.04	1.0	0.04
			1.00	0.76		0.71
	Category - Acceptability					
1.	Legal acceptance.	0.3	0.25	0.08	0.3	0.02
2.	Judicial acceptance.	0.8	0.25	0.20	0.5	0.10
3.	Police acceptance.	0.6	0.25	0.15	0.9	0.14
4.	Public acceptance.	0.6	0.25	0.15	0.4	0.06
			1.00	0.58		0.32
	Category - Cost Implications					
1.	Capitol equipment cost.	0.51	0.25	0.13	1.0	0.13
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	0.10	0.15	0.02	1.0	0.02
5.	Manpower operation cost.	0.05	0.15	0.008	1.0	0.008
			1.00	0.61		0.57

TABLE B-13.-RATING SYSTEM APPLIED TO A MULTANOVA 4FA WITH CAMERA USED BY A SINGLE OFFICER WHO OBSERVES BUT DOES NOT STOP SPEEDING MOTORISTS

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/notified.	0.21	0.15	0.03	0.9	0.03
2.	Speed detection capability.	0.79	0.12	0.09	0.9	0.09
3.	Accuracy of speed determination.	1.0	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.95	0.12	0.11	1.0	0.11
5.	Device reliability.	0.9	0.10	0.09	1.0	0.09
6.	Presentation and preservation of speeding evidence.	0.65	0.10	0.07	0.9	0.06
7.	Ability of device to counteract motorist evasion.	0.6	0.08	0.05	0.8	0.04
8.	Traffic safety compatibility.	0.9	0.08	0.07	0.9	0.06
9.	Traffic flow compatibility.	0.79	0.08	0.06	0.9	0.06
10.	Environmental (weather) compatibility	0.8	0.05	0.04	1.0	0.04
			1.00	0.73		0.70
	Category - Acceptability					
1.	Legal acceptance.	0.3	0.25	0.08	0.3	0.02
2.	Judicial acceptance.	0.8	0.25	0.20	0.5	0.10
3.	Police acceptance.	0.7	0.25	0.18	0.9	0.16
4.	Public acceptance.	0.6	0.25	0.15	0.4	0.06
			1.00	0.61		0.34
	Category - Cost Implications					
1.	Capitol equipment cost.	0.28	0.25	0.07	1.0	0.07
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	0.20	0.15	0.03	1.0	0.03
5.	Manpower operation cost.	0.09	0.15	0.01	1.0	0.01
			1.00	0.56		0.52

TABLE B-14.-RATING SYSTEM APPLIED TO A TRAFFIPAX IV/R WITH CAMERA USED BY A SINGLE OFFICER WHO OBSERVES BUT DOES NOT STOP SPEEDING MOTORISTS

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3) x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.49	0.15	0.07	0.9	0.07
2.	Speed detection capability.	0.73	0.12	0.09	0.9	0.08
3.	Accuracy of speed determination.	0.99	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.85	0.12	0.10	1.0	0.10
5.	Device reliability.	0.90	0.10	0.09	1.0	0.09
6.	Presentation and preservation of speeding evidence.	0.75	0.10	0.08	0.9	0.07
7.	Ability of device to counteract motorist evasion.	0.75	0.08	0.06	0.8	0.05
8.	Traffic safety compatibility.	0.85	0.08	0.07	0.9	0.06
9.	Traffic flow compatibility.	0.73	0.08	0.06	0.9	0.05
10.	Environmental (weather) compatibility	0.5	0.05	0.03	1.0	0.03
			1.00	0.77		0.72
	Category - Acceptability					
1.	Legal acceptance.	0.3	0.25	0.08	0.3	0.02
2.	Judicial acceptance.	0.8	0.25	0.20	0.5	0.10
3.	Police acceptance.	0.65	0.25	0.16	0.9	0.15
4.	Public acceptance.	0.6	0.25	0.15	0.4	0.06
			1.00	0.59		0.33
	Category - Cost Implications					
1.	Capitol equipment cost.	0.43	0.25	0.11	1.0	0.11
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	1.0	0.20	0.20	0.8	0.16
4.	Operation cost other than manpower.	0.10	0.15	0.02	1.0	0.02
5.	Manpower operation cost.	0.05	0.15	0.008	1.0	0.008
			1.00	0.59		0.55

TABLE B-17.-RATING SYSTEM APPLIED TO AN UNMANNED, FULLY AUTOMATIC MULTANOVA 4FA THAT PHOTOGRAPHS THE REAR OF SPEEDING VEHICLES

Factor Number	Description	(1) Factor Rating	(2) Factor Weight	(3) (1) x (2)	(4) Relative Confidence Value	(5) (3)·x (4)
	Category - Technical Effectiveness					
1.	Productivity of system in terms of fraction of speeders apprehended/ notified.	0.3	0.15	0.05	0.9	0.04
2.	Speed detection capability.	0.85	0.12	0.10	0.9	0.09
3.	Accuracy of speed determination.	1.0	0.12	0.12	1.0	0.12
4.	Ability to identify specific vehicle.	0.95	0.12	0.11	1.0	0.11
5.	Device reliability.	0.9	0.10	0.09	1.0	0.09
6.	Presentation and preservation of speeding evidence.	0.65	0.10	0.07	0.9	0.06
7.	Ability of device to counteract motorist evasion.	0.6	0.08	0.05	0.8	0.04
8.	Traffic safety compatibility.	0.95	0.08	0.08	0.9	0.07
9.	Traffic flow compatibility.	0.79	0.08	0.06	0.9	0.06
10.	Environmental (weather) compatibility	0.8	0.05	0.04	1.0	0.04
			1.00	0.77		0.72
	Category - Acceptability					
1.	Legal acceptance.	0.2	0.25	0.05	0.3	0.02
2.	Judicial acceptance.	0.5	0.25	0.13	0.2	0.03
3.	Police acceptance.	0.9	0.25	0.23	0.9	0.20
4.	Public acceptance.	0.6	0.25	0.16	0.4	0.06
			1.00	0.56		0.31
	Category - Cost Implications					
1.	Capitol equipment cost.	0.28	0.25	0.07	1.0	0.07
2.	Installation cost.	1.0	0.25	0.25	1.0	0.25
3.	Maintenance/repair cost.	0.57	0.20	0.11	0.7	0.08
4.	Operation cost other than manpower.	0.14	0.15	0.02	1.0	0.02
5.	Manpower operation cost.	0.12	0.15	0.02	1.0	0.02
			1.00	0.47		0.44

The fourth rating factor deals with vehicle identification. It is somewhat related to category 9, dicussed subsequently, but should not be confused with it. The identification rating is based on the assumption that, first of all, the system positively detects the fact that there is a speeding vehicle. The identification process then requires either the officer or the photographic components to determine which vehicle is the one that te system has detected. The Multanova system with the patented overlay for the photographic evidence is given the highest rating in this regard. It should enable the identification of the detected speeder in most (but not necessarily all) situations. A photographic template is supplied with the Gatso system to help identify the speeding vehicle from the photographic evidence, especially when more than one vehicle appears in the frame. The Gatso system is given the next highst rating in this category for this identification capability. The other cross-the-road radars are down rated somewhat in this regard because of their lack of the overlay principle. Likewise the cross-the-road radars used without photography are rated lower still, and the down-the-road system is rated lowest.

Device reliability accounts for downtime, malfunctions, etc. The Gatso is the only system that suffers appreciably on this account. This device experienced considerable downtimes and malfunctions during both the engineering field tests and preliminary law enforcement testing. The factor also includes the time required to set up the equipment, perform routine maintenance, calibration checks, etc. The Truvelo is assumed to require slightly more time for this purpose than the other systems.

The sixth technical effectiveness factor is the ability of the system to provide and preserve evidence. Those systems that provide only a visual speed display on a meter or dial were given a rating of 0.5. The Truvelo was rated slightly higher because of its capability to store the reading in a small memory unit and be recalled later. The photographic systems are rated higher, of course, but are not perfect. Experience shows that, for a variety of reasons, every photograph is not useable because of difficulties in reading the license number, a missing license plate, inappropriate processing, etc. The Multanova system was given slightly lower ratings when used with a camera compared to the other photographic systems because of the poor quality of the photographic evidence.

The seventh technical effectiveness factor is the ability of the system to counteract evasive tactics taken by motorists. These might include such activities as the use of radar detectors, sudden braking or swerving, purposely driving with dirty license plates, ducking or covering one's face (if frontal photography is used), intentionally driving in platoons or behind large trucks, etc. The Truvelo system, when used without cameras, is judged to be nearly perfect in this capacity. The down-the-road radar is most susceptible to evasive tactics because of the widespread use of radar detectors in the U.S.

The traffic safety compatibility factor deals with the adverse impacts that the very act of speed enforcement can have on traffic safety. Every system creates some hazards simply by its existence, and the knowledge of its existence by some motorists. Moreover, those systems that are installed immediately adjacent to the traveled way, even if in a parked vehicle, pose additional hazards. The major hazards, however, are judged to result from the need to stop the speeding vehicles (particularly in heavy or high-speed traffic) and the need to engage in pursuit of speeding vehicles.

The ninth factor deals with the system's ability to detect speeding when the speeding vehicle happens to be mixed in with other traffic, or when there are many speeders in close proximity. The down-the-road radar suffers greatly in this respect, of course. All of the manned systems are downgraded in this category, not because the officer cannot identify the vehicles, but because the officer, as a part of the system, cannot assimilate the information rapidly enough. This, of course, is not a great problem with the rapid photographic systems. Even with the photographic systems, however, if the speeding vehicles are too close together (e.g., side by side in adjacent lanes) the systems will not be able to detect the speeding in all cases.

The ability of the systems to operate under all environmental conditions is rated as the tenth technical factor. The automatic systems are rated higher than the manned systems because the equipment can be totally enclosed and operated despite the presence of high or low temperatures, rain, fog, etc. Nevertheless, they are not perfect because the photographic capabilities could be deteriorated by heavy fog, rain, snow, etc. The down-the-road (long range) radar is affected more than other systems by such environmental concerns.

The first acceptability factor--legal acceptance--is a measure of the likelihood that the system could be legally used. A rating of 1 was assigned to the currently used down-the-road radar (even though it is not legal in California). Likewise, all of the other systems, if used with a stop team rather than relying on photography, are given a rating of 1. However, very low ratings are applied to the use of totally automatic systems, because it is apparent that major law changes of some sort would be required for employment of such strategies.

The judicial acceptance of the currently used down-the-road radars is rated very high but not perfect. It is felt that the Truvelo system, even though it is currently not known in this country, would be very well received by the courts, because of its simplicity of operation. The other radar systems are rated down only slightly, because of their strong scieintific merit. The ratings for all the systems are slightly higher when used with backup photographic evidence to supplement the officer's statements. However, judicial acceptance may be somewhat lower for the automatic systems using only photographic evidence, even though they may become legal.

Police acceptance is assumed to be "perfect" for the currently used down-the-road radars, and somewhat lower for the other technologies when used in a manned mode. Police acceptance is somewhat higher when the equipment is used in an automatic mode. In other words, some of the police may prefer to use automatic systems and mail contacts rather than using systems where they personally become involved in contact with the public.

Finally, public acceptance is rated based on incomplete and imperfect data, but is presumed to be highest for the down-the-road radars currently in use and the Truvelo cable system which is conceptually not too different than systems that were commonly used in this country years ago. The other radar systems are rated somewhat lower but still fairly high as long as they are used with a manned stop team. They are rated slightly lower when used with a single officer not stopping violators and in a fully automatic deployment.

The numerical basis for the five cost factors is described earlier in this Appendix. The actual annualized costs used to generate the ratings are shown in Table B-2, and discussed in Chapter VIII.

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