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POTENTIAL FOR DRIVER ATTENTION MONITORING SYSTEM DEVELOPMENT

February 8, 1984

prepared for: National Highway Traffic Safety Administration
Office of Vehicle Research
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requested Jan 11 - six to seven weeks
delivered Feb 8 as requested
after RW rvw of Feb 5

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1.0 INTRODUCTION

The following document provides an overview of the potential value of research into driver attentional processes. Section 1 outlines the status of this research into driver attentional processes and provides capsule descriptions of the physical and psychological states which are related to reduced driver alertness. Section 2 outlines the statistical evidence of the relationships between driver attention and traffic accident data. Section 3 details the prior research in the area. Section 4 describes the technology currently available for sensing degraded alertness in drivers. Section 5 provides preliminary conclusions with regard to research directions in the area. The appendices provide reproductions of the material describing proprietary alertness devices and the NASS (National Accident Sampling System).

1.1 BACKGROUND

To a large extent the safe operation of any system which requires direct human control is dependent on the level of attention which the human controller provides. In particular, in motor vehicle operation the driver must sample the the driving environment, select the critical aspects of the environment, determine the proper response(s), make the response(s), and evaluate the outcome(s) of the response(s). To the extent that the driver does not sample the environment with sufficient frequency, or does not select the appropriate stimuli, or does not respond in a timely manner, safety will be degraded.

1.1.1 COUNTERMEASURES

Available driver alertness countermeasures include work-rest scheduling, educational campaigns, use of chemical stimulants and the detection of degraded alertness through sensor systems. In industrial and military settings, the alleviation of alertness-related safety problems are generally handled through the establishment and enforcement of duty schedules. The establishment of, and enforcement of work rest schedules is not a practical countermeasure for dealing with vast majority of road vehicle accidents, because they involve either private automobiles or self-owned truck operators. Educational and public information campaigns range from "defensive driving" courses through public service announcements prior to national holidays. Perhaps the most popular countermeasure is the use of legal and illegal chemical stimulants (particularly caffeine) to improve alertness.

This paper deals with the potential for the identification, evaluation, and refinement of techniques for detecting reduced driver alertness in the vehicle, in "realtime". A variety of devices have been developed and marketed as "alertness detectors". These devices have been widely adopted by the railroad industry and have found limited use in the trucking industry as well. A number of aftermarket devices are currently available to the private driver and at least one major manufacturer, Nissan Motors Ltd., has installed such a device in a production vehicle. The primary goal of these devices is to provide a signal to the driver that he or she is not adequately attentive, a common secondary goal is to arouse the driver.

1.1.2 ATTENTIONAL PROBLEMS

As Shinar, Zaidel, and Paarlberg (1978) note in their comprehensive review, lapses in driver attention can be assumed to be a significant contributory factor in the majority of traffic accidents. They cite estimates of the proportion of traffic accidents related to inattention, which ranges from 15 to 90 percent. This great range can, to a large extent, be attributed to differences in the definitions given to attention-related problems.

Shinar et al (1978) provide a list of dictionary definitions of attention, which define inattention as "a failure to pay attention". For the purpose of examining the impact of such failures on driving safety, it is valuable to consider physical and psychological states which are likely to degrade alertness and describe their impact on driving performance:

- Drowsiness: Except in cases where there is a known organic cause, such as narcolepsy, drowsiness can be attributed to a lack of sleep or a disturbance to the sleep rest cycle (dysynchronosis). There are complex hypotheses which explain the need for periodic sleep and dreaming, in human and infrahuman organisms. These relate to the diurnal hormonally regulated rhythms which cause the periodicity and the need for a reorganization of information acquired during waking hours, respectively. Whatever the causes of the need for sleep and concomitant dreaming, it is clear that "sleep deprivation leads to increased performance degradation as a result of an increase in the frequency of automatic periods of light sleep during enforced wakefulness and a heightening of the threshold of stimulation required to keep the individual from falling asleep" (Coffer and Apply, 1964). It is the occurrence of the light micro-sleeps which is a problem in highway safety. During these micro-sleeps, the driver neither attends to driving environment nor responds to it.

- Physical Fatigue: This can be a result of continued physical exertion and/or exposure to environmental stressors such as temperature and humidity extremes, excessive acoustic noise levels, and/or severe physical vibration. Physical fatigue is likely to result in distraction or an increased concern with internal stimuli and a concomitant decrease in attention to external stimuli. This change in focus from external to internal stimuli can be hypothesized to result in the missing of critical signals by the driver. Further, fatigue can result in a decrease in response accuracy by the driver, which can result in the requirement for a greater number of responses to achieve a desired maneuver, which will further distract the driver from concentrating on external events. Physical fatigue is often a problem in military and industrial settings. It is less likely to be a problem for passenger car drivers than for the operators of heavy trucks who are often subjected to very high noise and vibration levels.

- Excess Mental Workload: Here the driver has too many stimuli to attend to and/or too many responses to make per unit time. Skilled drivers learn to handle this situation by restricting their attention monitoring to the most critical inputs and meeting only the most critical control requirements. Less skilled drivers may choose to monitor inappropriate inputs or to make noncritical outputs. Some drivers may go into "saturation" and make no response or "freeze".

- Intoxication due to Alcohol, Drugs, or other Chemicals: Reductions in alertness are a direct or side affect of the use and/or abuse of a large number of substances. The exposure to pollutants, chief among them carbon monoxide, produces drowsiness, unconsciousness and eventual death. The effects of the ingestion of illegal drugs and legal medications vary as widely as do their chemical formulae, ranging from depression and drowsiness through agitation to hallucination. Although alcohol abuse by motor vehicle operators is perhaps the single greatest cause of traumatic injury in the U.S. today, there is still considerable debate with regard to behavioral changes caused by alcohol ingestion which result in dangerous driving practices.

- Simple Inattention: Here the driver is either not attending to the proper external stimuli or is not attending to any external stimuli. This behavior can be described as "daydreaming" or "wool gathering" or any of a number of colloquial terms. This inattention may be the result of any or all of the above-described problems or may simply result from introspective behavior by the driver or a distraction of the driver. The operational result is that the driver makes a delayed response, an inappropriate response, or no response at all.

1.2 GOAL

While the above-described conditions have a wide range of physiological concomitants, they have one particular behavioral similarity: all things being equal in non-alert state the driver is less likely to respond and less likely to respond in a timely and appropriate fashion to his or her environment than in the alert state. In a laboratory setting with a controlled environment where the reduction in response frequency is readily measured, the challenge is to reliably and accurately discriminate between changes in responses due to changes in driver alertness and those imposed by changes in driving conditions in the real world.

2.0 ACCIDENT STATISTICS

2.1 ACCIDENT DESCRIPTIONS

In order to develop hypotheses with regard to the impact of driver inattention on traffic accidents, data was obtained from the NASS files. The 1982 NASS was chosen because this is the first file to provide detailed information on driver role in traffic accidents. The following parameters were used in establishing the file:

2.1.1 VEHICLE FACTORS

- Vehicle Role: Striking/Struck

  Only striking and struck were used in order to reduce the ambiguity associated with driver actions that occur when the vehicle is involved in a non-collision accident such as a fire or the vehicle is involved in a chain reaction accident (striking and struck). Driver attention is clearly more important with regard to the role of the driver in the striking vehicle. However, in many cases, if the driver of the struck vehicle properly responds in a pre-accident situation, the accident can be avoided or its severity reduced. In order to reduce the ambiguity with regard to the role of the struck vehicle's driver, only cases where the vehicles were in motion were considered (see below).

- Vehicle Speed: Only cases where vehicles had speeds greater than 0.5 mph prior to the accident were considered.

2.1.2 DRIVER FACTORS

- Attempted Avoidance Maneuver: Two levels were examined: cases where no avoidance maneuver occurred and cases where any avoidance maneuver occurred.

- **Driver Drowsy:** This driver factor reflects cases where the driver being drowsy, asleep, or fatigued was considered the cause of the accident.

- **Driver Drugs-Medication:** This factor reflects cases where the use of "legal" drugs was considered the cause of the accident.

- **Driver Other Drugs:** In these accidents, the cause was attributed to the driver's use of illegal drugs.

- **Driver Inattention:** In these accidents, the cause was attributed to the driver's lack of attention.

- **Alcohol Abuse:** In these cases, the measured blood alcohol level of the driver was in excess of 0.07%.

- **Age of Driver:** Drivers were grouped by age: less than 25, 25 to 55, and more than 55 years old.

2.1.3 ACCIDENT FACTORS

- **Land Use:** Land use groups the accidents in terms of urban or rural site.

- **Time Period:** The day was divided into five time periods: Early AM, which represents accidents that occurred between the hours of midnight to 5:59 AM; AM Rush, all accidents that occurred between 6:00 AM and 9:59 AM; Mid Day, 10:00 AM to 3:59 PM; PM Rush, 4:00 PM to 6:59 PM; and Evening, which is from 7:00 PM to Midnight.

- **Road Alignment:** The data was grouped into accidents that occurred on curved sections of roadway and those that occurred on tangents.

- Number of Occupants: The data was examined to determine the influence of the presence of passengers in a vehicle (Occupants GT 1) on the accident. Vehicles having the driver as the only occupant are designated as occupant equal to one.

- Day of Week: The week was divided into weekdays (Monday through Friday) and weekends.

- Vehicle Type: All vehicles were grouped as being automobiles, motorcycles, buses, light trucks (including vans), medium/heavy trucks and all others.

2.2 NASS DATA

The NASS file provides a number of methods for estimating the role of attentional factors in crash avoidance. For the purposes of this document, the NASS file output was structured to examine the relationship between the above listed driver factors and crash frequency.

2.2.1 ALL COLLISIONS

A broad operational definition of driver inattention is **the attentional state where the driver fails to respond to a critical situation.** Table 1* represents breakdowns of the frequency of all "collision" accidents. where the role of the vehicle was known to be either striking or struck (vehicles whose roles were unknown or were involved in chain reaction collisions were not included), and the vehicles were in motion. In the 1982 NASS file there are 11,868 vehicles involved in accidents which meet these criteria. In these accidents

*All tables found in Appendix A.

- 2,665 or 22% were "striking" vehicles whose driver took no avoidance action prior to the collision;
- 1,838 or 15% were "struck" vehicles whose driver took no avoidance action prior to the collision;
- 5,916 or 50% were "striking" vehicles whose driver took avoidance action prior to the collision; and
- 1449 or 12% were struck vehicles whose drivers took avoidance action prior to the collision.

In short, in all collision accidents in which the vehicles were under way and a driver response might have conceivably avoided the collision or lessened the severity of the collision 38% of the drivers involved took no avoidance action. These relationships are depicted in Figure 1.

Examination of the other factors in Table 1 suggests that the drivers' age may be related to the probability of an avoidance response in the pre-collision situation. Figures 2 and 3 depict the differences in age distributions of drivers making avoidance responses and those not making such responses. Drivers over 55 years of age represent 18% of those making responses and only 11% of those not making avoidance responses. (differences of more than 2% are statistically significant).

2.2.2 INATTENTIVE

Table 2 represents breakdowns of the frequency of all "collision" accidents where the driver was judged to be **"inattentive"**, the role of the vehicle was known to be either striking or struck (vehicles whose roles were unknown or were involved in chain reaction collisions were not included), and the vehicle was in motion. In the 1982 NASS file, 946 or 8% of all collisions involved vehicles in accidents that met these criteria. In these accidents:

- 293 or 31% were "striking" vehicles whose driver took no avoidance action prior to the collision;

FIGURE 1

DRIVER RESPONSES IN ALL COLLISION ACCIDENTS

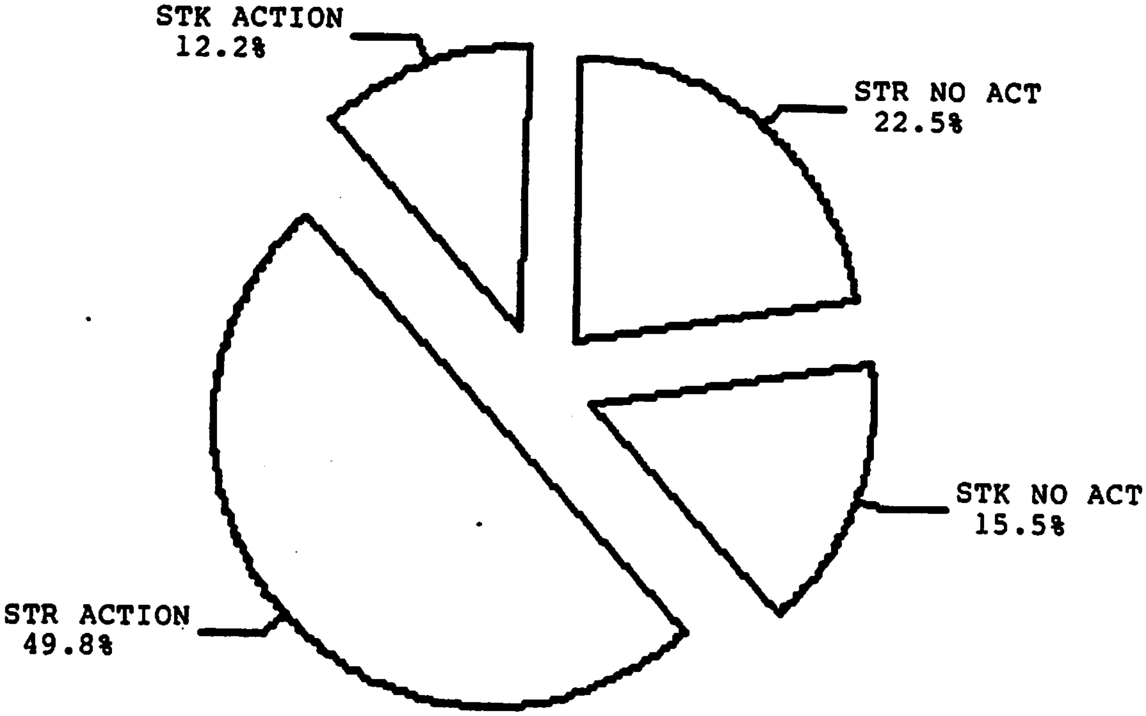


FIGURE 2

DRIVER RESPONSES IN ALL COLLISION ACCIDENTS - NO ACTION

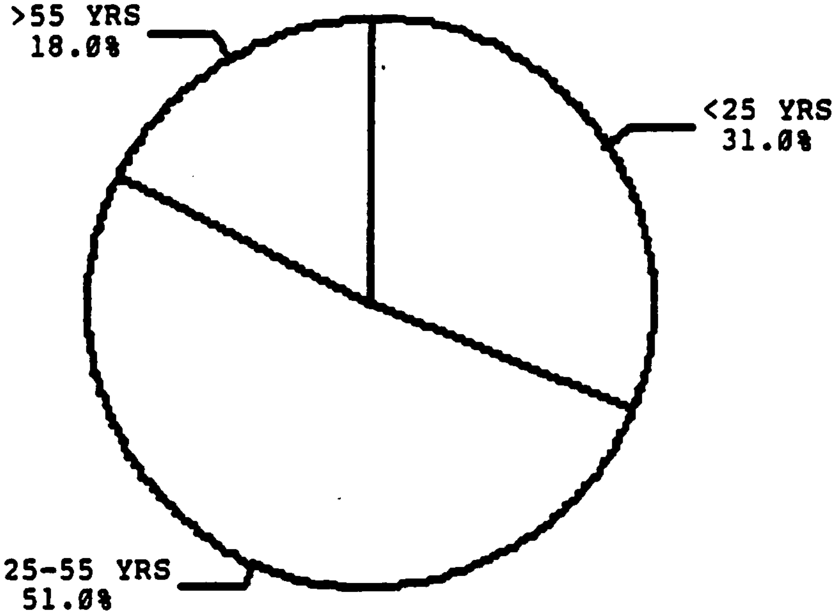
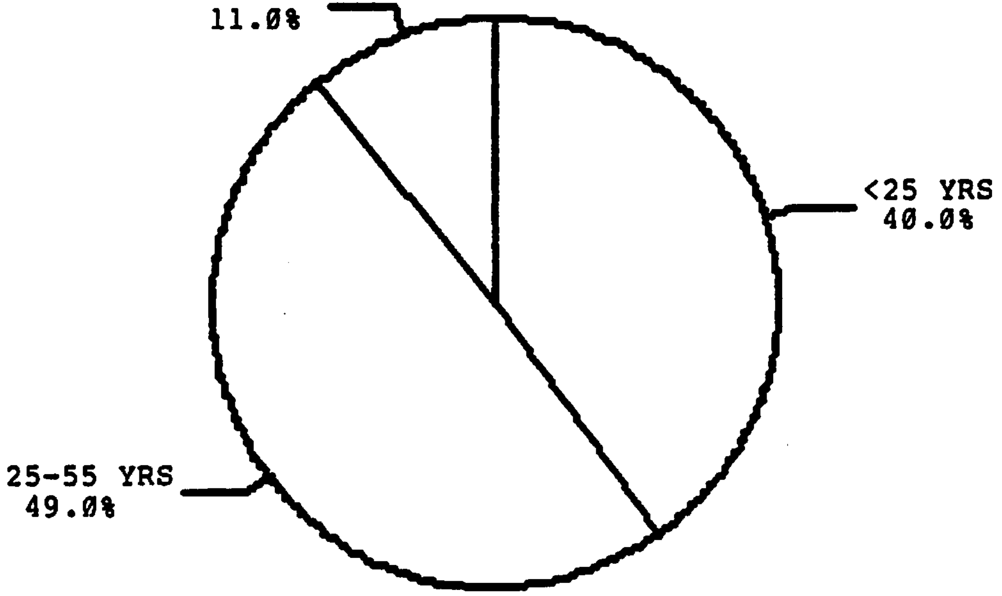


FIGURE 3

DRIVER RESPONSES IN ALL COLLISION ACCIDENTS - ACTION



- 80 or less than 1% were "struck" vehicles whose driver took no avoidance action prior to the collision;
- 509 or 53% were "striking" vehicles whose driver took avoidance action prior to the collision; and
- 64 or less than 1% were "struck" vehicles whose driver took avoidance action prior to the collision.

2.2.3 DROWSY

Table 3 represents breakdowns of the frequency of all "collision" accidents where the driver was judged to be **"drowsy"**, the role of the vehicle was known to be either striking or struck (vehicles whose roles were unknown or were involved in chain reaction collisions were not included), and the vehicle was in motion. In the 1982 NASS file, 176 or nearly 1% of all collisions involved vehicles in accidents that met these criteria. In these accidents

- 104 or 59% were "striking" vehicles whose driver took no avoidance action prior to the collision;
- 4 or less than 1% were "struck" vehicles whose driver took no avoidance action prior to the collision;
- 66 or 37% were "striking" vehicles whose driver took avoidance action prior to the collision; and
- 2 or less than 1% were "struck" vehicles whose driver took avoidance action prior to the collision.

2.2.4 DRUNK

Table 4 represents breakdowns of the frequency of all "collision" accidents where the driver had a blood alcohol level in excess of 0.07 %, the role of the vehicle was known to be either striking or struck (vehicles whose roles were unknown or were involved in chain reaction collisions were not included), and the vehicle was in motion. In the 1982 NASS file 376 or 3% of all collision involved vehicles in accidents meet these criteria. In these accidents:

- 157 or 42% were "striking" vehicles whose driver took no avoidance action prior to the collision;
- 11 or 3% were "struck" vehicles whose driver took no avoidance action prior to the collision;
- 195 or 51% were "striking" vehicles whose driver took avoidance action prior to the collision;
- and 13 or 3% were "struck" vehicles whose driver took avoidance action prior to the collision.

2.2.5 MEDICATION - LEGAL AND ILLEGAL

Tables 5 and 6 depict the drivers involved in accidents meeting the above mentioned collision criteria who were found to have used legal or illegal drugs prior to collision, respectively. In both of these categories the number of cases was less than 0.1% of the cases meeting the collision definition.

3.0 DRIVER/VEHICLE MONITORING

A summary of our current state of knowledge of indicators of driver inattention is presented in this section. Shinar et al (1978) documented a comprehensive review of related studies of the concept of attention as well as studies related to the problem of attentional performance. In preparation for the present report, additional studies of operator performance conducted since 1978 were also reviewed to update the study by Shinar. The results of these recent studies confirm both the general conclusions drawn in previous studies and the complexity of the problem of driver attention/inattention.

In the following sub-sections a few definitions of terms are given first, and then a summary discussion of indicators of driver inattention. The definitions are given primarily to help establish a point of reference. The discussion of indicators is meant to reflect an interest in the development of operational countermeasures.

3.1 DEFINITION OF TERMS

Many investigators as well as Shinar and his coauthors, have noted the ambiguity of such terms attention, alertness, arousal, and vigilance. They are often used interchangeably, with various authors referring to them as a source or condition resulting in the certain operators behavior, and other authors defining the term or condition operationally in terms of behavior. For consistency and continuity, the definitions of these terms used by Shinar and his co-workers will be used in this review.

The dominant connotation of the term arousal is a general readiness to receive and respond to environmental stimuli. The term also has a strong connotation of specific physiological activity. Alertness connotes primarily a psychological state and a more specific readiness to receive and respond to a broad chain of environmental stimuli. Attention will be used in this review to connote the psychological state of readiness to receive and respond to **task-relevant** information. Thus an aroused or alert individual is not necessarily attentive.

3.1.1 DIMENSIONS OF ATTENTION

Shinar presented four useful definitions of dimensions or attributes of attention, these are 1) intensity, connoting a level of total effort; 2) distribution, referring to the division or allocation among sources of information; 3) regularity, connoting maintenance of level and continuity through time; and 4) mode of control, referring to the level of active control and direction of attention by the operator.

3.1.2 OPERATOR ATTENTIONAL STATE

It is apparent that the defined dimensions or attributes of attention are not independent, and measurements may be obtained to some degree on each of them at a given moment. From moment to moment, however, a driver may exhibit one or more of the attributes to a greater of lessor degree. For the purpose of this review, therefore, a loosely defined concept of attentional state will be used to characterize a driver, with the state defined as some function or combination of weighted values of each of the separate dimensions or attributes.

3.1.3 ATTENTIONAL PERFORMANCE

Attentional performance refers to the accomplishment of activities related to the acquisition of job relevant information. To have maximum utility an activity must be objective, quantifiable, and directly related to an attention attribute. In this context, inattention is defined by insufficient performance of attentional activities related to one or more attributes of attention.

3.1.4 INATTENTION DETECTOR

A detector of inattention must be a measurable event or state or activity of the driver or the vehicle. A useful detector should be at least an indirect measure of attentional performance. An ideal detector would be some direct measure of attentional performance. Eye movements for example, are a direct indicator. However, eye movements are not an ideal detector since an appropriate movement or fixation does not assure perception of relevant information, and lack of measurable movement or fixation does not necessarily indicate the lack of perception of relevant information.

The greater number of indicators are indirect measures of attentional performance in that they are measures of driver activity such as steering, or of vehicle dynamics, such as RMS heading angle, which may vary with changes in the driver's attentional state. A third class of indicators, which includes measures of driver physiological states, are at best gross measures of possible changes in attentional performance and in most cases are an indicator of environment and task requirements, or a driver state consistent with inattention.

3.2 INATTENTION INDICATORS

3.2.1 PHYSIOLOGICAL INDICATORS

In general, physiological indicators are measures of a driver state which may be correlated with, but are not necessarily indicators of, insufficient attentional performance. Measures of heart activity and brain electrical activity have received the most attention.

3.2.1.1 HEART RATE AND HEART RATE VARIABILITY

A driver's heart rate is usually found to decrease during extended periods of driving under uneventful conditions. Heart rate variability tends to increase under these conditions. These measures have been commonly, but not invariably, correlated with changes in driver control performance and changes in brain electrical activity under these conditions. Both measures are affected by many psychophysiological and environmental measures, and indicate a relaxed, but not necessarily inattentive state.

3.2.1.2 BRAIN ELECTRICAL ACTIVITY

Selected frequencies of brain electrical activity have been found in laboratory studies to be useful markers of a subject's transition from an alert to a relaxed, sleepy stage. Alpha activity is often observed after extended periods in a low demand task and is correlated with changes in other measures of attention performance. Theta and delta activity have also been observed during extended periods in a low demand task. Appearance of frequencies is usually interpreted as indicating that a subject is asleep. Their appearance has been noted in truck drivers and is correlated with other measures such as vehicle lane drift.

There has been some interest in event-stimulated (evoked) cortical potentials. A positive component, P300, has been found to be correlated with attentive behavior, but not inattention.

Comment:

> Heart rate and heart rate velocity appear to have little potential for detecting inattention. Measures of brain electrical activity appear to good detectors of inattention. Their primary utility, however, appears to be a tool for research and development of other detectors. These measures typically require the processing of several time samples of data to extract the desired information, thus, requiring extended time and complex instrumentation. The most critical limitation of their practical utility, however, is the fact that driver attentional performance is insufficient for a significant period of time before the occurrence of such activity.

3.2.2.3 OTHER PHYSIOLOGICAL INDICATORS

Several other measures of physiological activity have been used by investigators. These include, for example, muscle electrical activity, skin electrical activity, respiratory patterns, critical flicker frequency, pupil size, and gross body activity. Changes in these measures have been found to be inconsistently correlated with length of time of driving or subject fatigue. These measures are strongly affected by many extraneous variables, however, and evidence for correlation with a driver's attention state is so weak and inconsistent that they appear to have no potential for use detectors of inattention.

3.3 OPERATOR BEHAVIOR

3.3.1 PHYSICAL

3.3.1.1 LOOKING BEHAVIOR

Looking behavior is the most direct measure of attentional performance although fixation does not necessarily indicate attending. Conversely, the lack of fixation does not indicate lack of perception.

In past investigations it has been found that eye movements become sluggish with the development of driver fatigue due to sleep debt, extended visual performance while driving for long periods, and with alcohol intoxification. With extended time, the number of pursuit movements has been found to increase, but the behavioral velocity of eye movements decreased. Extended activity has also been found to result in a narrowing, and change of the field of visual search. Alcohol intoxification has also been found to result in a narrowing of a driver's field of search and intoxicated drivers tended to fixate passing cars less frequently. Recent research shows that the focus of attention and an apparent selective narrowing of the attentional field as the result of increased task demands.

A detailed analysis of eye movements has indicated that with increased driver BAC mean dwell time and variability increased, dwell frequency decreased, pursuit frequency increased but pursuit dwell time was variable, and mean saccade durations increased.

3.3.1.2 BLINK RATE

Typically, blink rate decreases and blink duration increases with time during extended periods of driving. Conversely, it has been observed that blink rate decreases with increases in mental workload. Since blink rate and duration affect the total time spent in the acquisition of visual information, they may be considered to be gross measures of attentional performance. They are probably more useful, however, as indicators of a driver state, such as drowsiness which is correlated with an inadequate attentional state. Blink activity does not appear to have great potential for on-road application. Activity would be difficult to monitor in a normal driving situation and detectable changes may appear only after a significant period of insufficient attentional performance. It may be of use in research and development in combination with measures of eye movements.

Comment:

> Eye movements are a direct, but not infallible measure of attentional performance. Eye movement patterns change with changes in conditions considered to result in changes of driver attentional state. Measurement is difficult, complex equipment is required, and data processing requirements are onerous, however. Thus it appears that the measure of attentional performance has little potential for on-road application in the reasonably near future. It is, however, an excellent measure to be used in research and development of other detectors.

3.3.1.3 SUBSIDIARY TASK PERFORMANCE

In studies of driver attention, performance on subsidiary tasks has been used as an indicator of spare capacity, distribution of attention, and of inattention. There is little evidence suggesting that secondary task performance is a useful indicator of inattention. There is considerable evidence, however, that requirement of performance on a secondary task can result in degraded performance on a primary task. Subsidiary tasks have been used as a measure of monitoring drivers in locomotive operations, but evidence of their effectiveness in inconclusive. On the basis of available data, it appears that the most useful approach to the use of subsidiary task performance would be to use it as an indicator that a driver has correctly acquired critical information. With this approach, an interactive system is required to signal to the driver a specific need for attention, to evaluate the driver's response, and to provide subsequent feedback to the driver.

3.3.2 DRIVER'S CONTROL PERFORMANCE

3.3.2.1 STEERING MOVEMENTS

A range of specific measures have been used to study driver steering performance, but the essential finding is that steering wheel reversal rate decreases during extended periods of driving, the number of fine steering wheel movements decreases and the number of course movements increases. Similar changes have been found with drivers under the influence of depressants, such as alcohol or secobarbitol. Characteristic changes in steering movement patterns have also been observed under conditions requiring a relatively stable change in driver attentional state. For example, as with the imposition of a secondary task to be accomplished while driving. Similar characteristic changes have also been observed under conditions requiring a transitory change in attentional state or in meeting an oncoming vehicle on a two-lane roadway.

Comment:

> Driver steering performance seems to directly reflect attentional state and attentional performance. Measures of steering performance have high potential utility for detection of inattention. Further work is required to define both sensitivity and the discriminative power of measures with respect to the driver's attention state and level of attentional performance.

3.3.2.2 OTHER MEASURES OF CONTROL PERFORMANCE

Very few investigators have used accelerator and brake pedal activity as measures of performance in studies most relevant to the problem of driver inattention. What data is available provides little basis for suggesting a relationship between brake pedal activity or accelerator pedal activity and any dimension of attention. These activities are strongly conditioned by personal and environmental variables and appear to have no potential as detectors of inattention. They have been found useful in some studies of individual differences.

3.3.3 VEHICLE DYNAMICS

The term vehicle dynamics is used loosely in this section to refer to measures of relative vehicle motion and position with respect to the roadway or other vehicles.

3.3.3.1 LATERAL POSITION

The common finding in studies of drivers in extended, low demand driving is that lane position error and lane position variability increase with time of driving. Similar results have also been obtained with drivers under the influence of depressant drugs such as alcohol or secobarbital. Lateral drift and lateral acceleration have also been found to increase when drivers are asked to perform a secondary task while driving.

3.3.3.2 LONGITUDINAL POSITION

For convenience, a number of disparate measures of vehicle velocity and position with respect to other vehicles are included. Most commonly, it has been found that speed variability increases during extended periods of driving under monotonous conditions. A similar increase in speed variability and increased headway variability has been observed with drivers under the influence of a depressant such as alcohol or secobarbital. In general, measures of mean headway distance have been found to be a consistent indicator of a changed driver state.

3.3.3.3 HEADING ERROR (Yaw)

Such measures as heading error, yaw rate, the number of yaw reversals greater than 2° and the standard deviation of yaw angle have all been found to increase during extended periods of driving.

Comment:

Measures of driver control activity and vehicle dynamics are perhaps the most consistent and useful indicators of driver attentional state. Measurement of lateral position error does not necessarily require a direct lane sensing system since lane drift and change in relative lane position may be inferred from measures of steering wheel activity, yaw and lateral accelerations, for example. Measures of vehicle position relative to other vehicles are strongly affected by personal and environmental variables. However, considering the rapid advances in micro-electronics and miniaturized radar systems, they should be considered for use as an element in combined signature systems or for use in stand-alone alerting systems.

3.4 COMPLEX PERFORMANCE SIGNATURES

On the basis of a review of the available data, it can be concluded that there are a number of indicators of driver inattention which have potential utility for countermeasure applications. Considered singly, these indicators have very limited discriminative power. Individual indicators are usually, but not invariably, observed to appear under apparently similar conditions, and the lack of appearance of a given indicator does not indicate inadequate attentional performance. On the basis of the results of some investigations, however, it appears that discriminative power may be obtained with combinations of indicators of attentional state plus indicators of the driving environment.

3.4.1 STATISTICAL PROCESSING

A number of investigators have used multi-variate statistical techniques to identify combinations of driver performance measures with greater discriminatory power than single indicators. A number of techniques have been used for data analysis and combination. These include: factor analysis, canonical correlation, multi-variate linear regression, and multi-variate discriminant functions. In most cases, the focus of interest has been on questions of individual differences, and investigators have been successful in developing appropriate combinations of measures to predict individual membership in groups of interest. An example of this approach is shown in Figure 4.illustrating the complexity and magnitude of the required analysis. It is obvious that this technique may be useful only as a research and development tool.

3.4.2 MODEL BASED SIGNATURES

In recent years there has been considerable interest and success in the development of useful driver/vehicle models. Most of the work has been directed to the development of either optimal control models, using a state space yaw descriptive approach, or quasi-linear model using describing functions to include operator non-linear characteristics. In attempts to model driver behavior, quasi-linear models have been developed to the greatest degree.

These models appear to provide an excellent basis for the development of complex performance signatures indicating driver inattention. They provide a known conceptual framework and include model parameter which can be interpreted as reflecting physiological and psychological states as well as performance characteristics of the driver. Included, for example, are parameters related to steering wheel motion and vehicle heading deviation. Other parameters represent more general driver physiological and psychological states such as reaction time and tolerance for error. In addition, other parameters, such as cross-over frequency, indifference, ratio, and remnant are related to more complex details and interactions of elements of driver

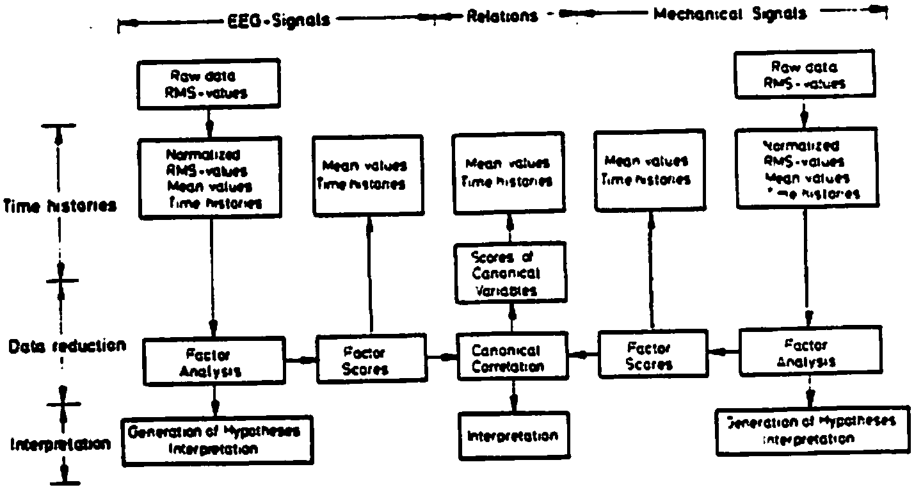


Fig. 13. Flow chart of evaluation methods employed.

	FAKTOR		
Variable	E1	E2	E3
E1F1	-.77		
E2F1	+.58		+.53
UA1		+.76	
UA2		+.81	
AZ1		+.58	+.69
AZ2			+.83
EVER1	+.90		
UAVER	+.55		
AZVER		-.72	
Varianz-anteil	50%	33%	17%

Fig. 14. Simplified factor loading matrix for EEG signals.

	FAKTOR			
Variable	F1	F2	F3	F4
LAMU1				
LAMO1	+.86			
LAMG1	+.77			
ALPU1		+.76		
ALPO1		+.80		
ALPG1		+1.00		
PSIU1			+.94	
PSIO1	+.89			
PSIG1	+.61		+.76	
KAPU1				+.86
KAPO1	+.95			
KAPG1	+.67			+.71
Varianz-anteil	51%	25%	16%	8%

Fig. 15. Simplified factor loading matrix for mechanical signals.

Figure 4

performance. Changes of the values of these parameters have been found in experiments in which subjects drove for extended periods, under the influence of alcohol, and with conditions required diversion of attention.

A brief discussion of operator modeling, parameter identification techniques and application to system failure detection is given in Appendix B to the report.

4.0 DRIVER ALERTNESS MONITORS

4.1 OBJECTIVE AND INTRODUCTION

In this section we will review the state-of-the-art in driver alertness monitors. There are, at present, a limited number of such devices that are commercially available. These range from the unsophisticated head-droop alarm to the microprocessor-based system of steering wheel driving pattern/driving time patterns that is available in Japan on Nissan's Bluebird line of vehicles. These and several devices that were at one time commercially available, are detailed in Section 4.2.

Indicators of inattention have been extensively studied, including such physiological measures as EKG, EEG, pulse and heart rate, and eye blinking. Behavioral indicators would include looking patterns, driver steering wheel use, accelerator and brake applications, lane drift, closure rate, etc. These indicators and their potential for development into practical monitors are discussed in Section 4.3.

Although not directly related to driver attention per se, the status of systems related to the vehicle and its environment are considered in Section 4.4. These include radar warning and braking systems, navigational aids, roadside monitors and automated highway systems. These systems could be considered as part of a multi-variate approach in the development of a driver alertness monitor.

The state-of-the-art in automotive electronics will be briefly reviewed in Section 4.5. The practical utilization of any of the aforementioned devices depends, to a large extent, on the development of sophisticated electronics for sensing, data handling and analysis.

4.2 DRIVER ALERTNESS SENSORS

Several devices have been developed over the years to monitor driver alertness and to stimulate the driver when his performance degrades due to inattention or drowsiness. Appendix A contains sales brochures and articles on each of the driver alertness indicators. Table 4.1 summarizes these devices.

4.2.1 COMMERCIALLY AVAILABLE INDICATORS

Three driver alertness indicators are currently available at the consumer level: The Reli "Stay-A-Wake", the Slarner "Driver Alert Warning Device" and the Nissan "Safety Drive Advisor". The Ford Motor Company's "Owl Driver Alertness Aid" and the Safex "Drive Alert" were marketed several years ago, but are no longer being produced.

4.2.1.1 RELI "STAY-A-WAKE"

The Reli Corporation is based in Markle, IN. Reli has developed the "Stay-A-Wake" alertness alarm that senses the vehicles speed through a connection to the speedometer cable and monitors steering corrections through an optical sensor tape that is mounted on the steering column. An alarm will sound if no steering motions, whether reversals or advancements, are made within a three to seven second period. The driver selects the appropriate interval by manually adjusting the alarm. Approximately one second after the alarm begins the cruise control will be defeated and the vehicle's horn will sound. The excess speed function alerts the driver at the selected speed. The alarm increases in intensity if the selected speed is exceeded. The device is powered by the vehicle's electrical system and retails for approximately $170.

4.2.1.2 SLARNER "DRIVER ALERT WARNING DEVICE"

The Slarner "Driver Alert Warning Device" was developed and patented by a French corporation. It is worn on the ear of the driver like a hearing aid and operates with a mercury level switch that is engaged when the driver's head drops below normal, as when the driver begins to nod from drowsiness. The device emits an 86dB alarm at 2000 Hz and is adjustable to 18 pre-selected positions.

TABLE 4.1
DRIVER ALERTNESS MONITORS

Monitor System	Sensor	Measurement Dimension	Active or Passive (1)	Obtrusive or Remote (2)	Advantages	Disadvantages	Availability	Cost
Reli "Stay-A-Wake"	Optical Transducer	Steering Rate	A	R	Alerts driver when steering wheel movement rate drops below a given rate.	Standard steering movement rate must be set by driver. System effectiveness can be defeated.	Available from the manufacturer	$170
	Voltage	Vehicle Speed	A	R	Will sound an alarm when vehicle reaches or exceeds a set speed.	Speed at which alarm sounds is set by driver.		
Slarner "Driver Alert Warning Device"	Switch	State Change	A	O	Sounds an alarm when driver's head droops.	Warning does not occur until the driver is asleep.	Available from AAA	$33
Safex "Drive Alert"	Switch	State Change	A	O	Sounds an alarm when driver's head droops.	Warning does not occur until the driver is asleep.	No longer available	
Nissan "Safety Drive Advisor"	Optical/ Velocity Sensor	Rate & Frequency	P	R	Monitors and records driver's initial steering reversal rate and alerts the driver if steering reversal rate differs from this standard.	Little detail of operational principle is known to date.	Available on Nissan Bluebird models. Not imported into USA.	$85 (approx)
	Electronic Clock	Elapsed Driving Time	P	R	Alerts driver to take periodic breaks. Interval between signals is decreased by activation of headlights or windshield wipers.			
Life Technology/ Ford "Owl"	Optical Sensor	Rate	P	R	Monitors and records driver's initial steering reversal rate and alerts the driver if steering reversal rate differs from this standard.	Standard steering reversal rate can be adjusted by driver. System affectiveness can be can be defeated.	No longer available	

(1) Active requires and passive does not require activity on the part of the driver.

(2) Obtrusive requires and remote does not require physical attachment to the driver.

The "Driver Alert Warning Device" is manufactured in the Orient and is being distributed in the United States by the American Automobile Association (AAA) for $33.

4.2.1.3 NISSAN "SAFETY DRIVE ADVISOR"

The Nissan "Safety Drive Advisor" was developed for the NRV-II (Nissan Research Vehicle) and is available on the Nissan "Bluebird", which is being marketed in Japan. The "Safety Drive Advisor" monitors the driver's steering wheel reversal rate and records elapsed driving time.

After two hours of daytime driving, the device sounds a buzzer and lights a display in the form of a coffee cup for approximately ten seconds, advising the driver to take a break from driving. A series of lights are activated, one every 30 minutes, and an alarm will sound every hour for a maximum of three hours, until the driver turns the ignition off or allows the car to stand idling for a period of more than five minutes. The "Driving Time Monitor" function will alert the driver after the next period of driving equal to four times the resting time, and will continue to encourage the driver to rest at this time interval. When the windshield wiper and headlight switches are activated, indicating night driving and adverse weather, the time interval between driver rest warnings is reduced 20%, 10% for each, and the light warning indicators will signal at 25-minute intervals.

The "Safety Drive Advisor" will engage the "Weary Driving Monitor" at vehicle speeds greater than 50 km/hr (approximately 30 mph). The device monitors the driver's normal steering reversal rate for the first ten minutes of driving through a photo-optical steering angle and velocity sensor in the steering wheel. The system monitors the steering pattern and will sound an alarm and light an indicator regardless of elapsed driving time to alert the driver of his decrease in performance. The NRV-II version includes a voice simulator that warns, "You are getting drowsy. Please rest." If the control unit senses brake, turn signal, clutch or gear level actions, the system will disregard steering reversals for a predesignated time interval. The unit identifies a winding road through steering signals and, again, disregards steering motions for a predesignated period.

The development of the "Safety Drive Advisor" has been conducted at Nissan's Central Laboratory over the past ten years. The optical and velocity steering sensor is an integral part of Nissan's electronic power steering system, which is offered on Bluebird models. The unit cost is said to be approximately $85.

4.2.2 POTENTIALLY AVAILABLE INDICATORS

Two driver alertness indicators, the Life Technology Inc./Ford "Owl" and the Safex "Drive Alert", are not commercially available at this time.

4.2.2.1 LIFE TECHNOLOGY INC./FORD "OWL"

In the late 1960's, the Ford Motor Company conducted research into driver behavioral patterns, which resulted in the development of an experimental driver attention aid. The device records the driver's steering reversal rate under normal conditions and continually compares that profile to the driver's long-term performance. Life Technology Inc., of Concord, California, was licensed to develop the patented Ford device into a commercially available product.

The "Owl" tracks and records the driver's steering wheel reversal rates for the first three minutes of driving at a speed greater than 35 mph as the standard and compares that profile with continuing driver response. If the reversal rate drops too low, usually indicating inattention, an alarm sounds. If the reversal rate becomes too high, potentially indicating that the driver is going too fast for the road conditions, a light is turned on, cautioning the driver to reduce speed.

Several of the "Owl" devices were manufactured and tested by Ford in the early 1970's. Ford conducted field tests of the "Owl" with a variety of drivers, including truck and bus drivers, race car drivers, astronauts, and drivers selected from the general public. A representative of Ford's Driver Safety Division, who participated in the "Owl" Test Program, stated in a recent telephone conversation that the test drivers eventually tired of the warning system and turned the level control too far down in order to defeat the system.

4.2.2.2 SAFEX "DRIVE ALERT"

This product was marketed by Safex of Manchester, Connecticut, who are no longer in business. The device is identical in operation to the Slarner "Driver Alert Warning Device", in that it emits an 86dB, 2000 Hz alarm when the mercury level switch engages as the driver's head droops. The "Drive Alert" also is worn on the Driver's ear, and can be set to 18 pre-selected positions. The device weighs less than an ounce, runs on batteries and retails for $30.

4.3 POTENTIAL INDICATORS OF DRIVER ALERTNESS

Table 4.2 lists the various physiological and behavioral indicators of inattention, how these indicators are sensed and some of the advantages and disadvantages of the indicators relative to their potential development as a practical monitor of inattention. Many of these indicators have been studied in an attempt to relate them to attention, work load, and vigilance. The status of these research efforts was summarized in Section 3.0 of this report. These indicators have been monitored in both laboratory/simulator experiments and in actual road studies. In general, Table 4.2 indicates that the sensor techniques for monitoring physiological indicators of inattention are obtrusive in nature, may require complicated data handling and would not lend themselves to a near-term, practical driver monitor. However, the informational content of some physiological indicators, such as EEG, may be the best indicators of the driver's state of arousal. For the present, these physiological indicators will continue to be of more value as experimental tools used in a program to develop practical driver attention monitors.

The behavioral indicators offer more immediate promise for adaptation to a practical driver alertness monitor. This is because they generally manifest themselves in a vehicle-related response (operator control performance) and are more adopted leant to passive monitoring. These indicators include steering,

TABLE 4.2
PHYSIOLOGICAL INDICATORS OF DRIVER ATTENTION

Indicator	Sensor	Measurement Dimension	Active(1) or Passive	Obtrusive(2) or Remote	Advantages	Disadvantages
Heart Rate & Heart Rate Variability (EKG)	Electrode or Transducer	Voltage or Pressure	P	O	Easy to monitor Could be made remote by incorporation into steering wheel Easy to interpret	May require detailed spectral analysis Individual variations are large
Brain Electrical Activity (EEG)	Electrode	Voltage Amplitude and Frequency	P	O	Established relationship to fatigue and and drowsiness	Difficult to monitor or interpret No remote sensing possible in the near-term
Skin Conductance and Electrodermal Response (EDR)	Electrode	Voltage Resistivity	P	O	Could be made remote by incorporation into steering wheel	Individual variations in galvanic skin response are large Relationship to inattention not well established
Muscle Electrical Activity	Electrode	Voltage Amplitude and Frequency	P	O	Relatively easy to monitor	Relationship to inattention weak Remote monitoring not possible in near-term
Body Activity	Observer or Switches	Number of Movements State Change Frequency	P	R		Requires observer No established correlation to inattention
Respiratory Pattern	Transducer	Frequency	P	O		Difficult to monitor Correlation with vigilance inconsistent
Critical Flicker Frequency	Self-Assessed	Null Frequency	A	R	Easy to administer Could be built into vehicle dashboard	Driver would have to stop vehicle to administer Weak correlation with fatigue
Head Nod Angle	Switch	State Change	P	O	Cheap, Commercially Available	Measures last stage of drowsiness

(1) Active requires and passive does not require activity on the part of the driver.

(2) Obtrusive requires and remote does not require physical attachment to the driver.

TABLE 4.2 (continued)
BEHAVIORAL INDICATORS OF DRIVER ATTENTION

Indicator	Sensor	Measurement Dimension	Active[(1)] or Passive	Obtrusive[(2)] or Remote	Advantages	Disadvantages
Steering wheel reversals	Potentiometer, optical or magnetic transducer	Rate and angle	P	R	Easy to monitor Studied extensively Commercially available	Affected by vehicle/driving environment Individual variations
Accelator pedal movement	Linear potentiometer	Rate and amplitude	P	R	Easy to monitor	No established relationship to attention Individual Variations
Brake Pedal Movements	Linear potentiometer, pressure transducer	Rate and pressure	P	R	Easy to monitor	No established relationship to attention Individual variations
Vehicle position (Longitudinal, Lateral, and Heading)	Observer, sensitive guidance system, road-side edge monitor, radiation detector	Frequency, amplitude and angle, relative distance	P	R	Correlated with alcohol and drug use	Difficult to monitor Complex interactions
Looking behavior	Observer, TV monitor, oculometer	Eye position and fixation frequency, pattern and duration	P	O or R	Correlated to all dimensions of attention Can be made remote	Interpretation difficult Not useful in real time
Blink rate	As above	Rate and duration	P	O or R	Can be measured remotely	Weakly correlated with attention
Secondary tasks	Many Variations Usually Tracking		A	R	Can be a simple device	Distracts from main task

accelerator, brake, shift, and clutch control as well as vehicle heading. These indicators can be sensed using existing, relatively simple technology and require no action on the part of the driver outside of normal driving activities. In fact, these indicators, except for headnoding, are the ones usually adapted for the commercial market (see Section 4.2). Other behavioral indicators of inattention, such as eye movements and vehicle closure rates, can be monitored, but require more sophisticated technology. For instance, Honeywell has developed the oculometer-type device that remotely monitors eye movement over a wide-range of head movement. This device has been used in both simulator and real-world vehicle experiments. Lane drift and measurement of vehicle closure rates also require sophisticated technologies that could include radar, sonar, and optical tracking devices, roadside lane monitors with appropriate vehicle sensors, and extremely sensitive on-board guidance systems, either inertial or satellite based. Devices operating on these principles are discussed in Section 4.4. The costs, reliability, and practicality may preclude the use of such systems in the near-term.

None of the presently available or potential indicators of inattention can individually, be considered the ideal alertness monitor. We recommend that the most fruitful approach would lie in the development of a multi-variate behavioral system similar to Nissan's.

4.4 OTHER RELATED MONITORS

This section will briefly review the status of systems available to complement the development of driver alertness monitors. These systems include radar sensing (warning and braking), roadside monitors, navigational aids and automated guidance highways.

4.4.1 RADAR SENSING

Radar sensing can be used to alert the driver of an impending unsafe condition or to actually apply the vehicles brakes. In a review of these systems performed for NHTSA in 1981 by Kinetic Research Inc. ("Collision Avoidance System Cost

Benefit Analysis"), ten collision avoidance systems were identified as functional or under development. The manufacturing companies were American, European, and Japanese. Kinetic Research concluded that radar braking systems would be more effective in avoiding accidents than simple warning devices. They would be most effective in reducing rear impact collisions (a reduction in accidents of 26% to 62%) and least effective in reducing side collisions (a reduction in accidents of 3% to 4%). The ultimate costs of such systems were difficult to calculate, but they concluded that the costs and benefits would be equal, based on 1979 dollars. False alarms were difficult to quantify and were of concern. No time-frame for incorporation into the vehicle fleet was considered.

With respect to vehicle closure rates, one of the features of Nissan's NRV-II safety vehicle was a radar auto-cruise (see Appendix). With the vehicle operating under cruise control, the radar senses the distance to the vehicle in front and displays this information along with the calculated safe distance. The system warns the driver and deactivates the cruise-control if the NRV-II comes to close the vehicle in front. The cost of such a system is not given.

4.4.2 NAVIGATIONAL AIDS

Navigational aids are available in several commercially marketed vehicles in Japan. Such systems have been developed by Nissan, Toyota, and Honda. Ford is developing a system in the U.S. as is Volkswagen-Siemens in Germany. Honda's system is the most sophisticated and is available on the Japanese Accord-equivalent for $1300. The device works on a gas-tube "gyro" system. Although its location accuracy is not given, the device has problems sensing minor directional changes such as those encountered on multi-lane highways. Ford Motor Company's navigational system will locate a vehicle within 1200 feet by satellite guidance. The VW-Siemens system uses an on-board magnetic field sensor, the vehicle's longitudinal axis, and speedometer distance pulses to compute and display a vehicle's direction and distance to destination. In addition, the system uses infrared transmitters on traffic lights to tell the driver how best to reach their required destination (such a concept could also be used as a driver warning response system similar to that used on trains, where the train operator is required to perform a specific function such as pressing a button when given a certain cue).

Toyota also has available a sonar-based back-up warning system. These devices are viewed as indicators of the state of vehicle technology, and in the long term, as part of an integrated multi-variate crash avoidance system.

4.4.3 AUTOMATED HIGHWAY SYSTEMS

The ultimate technique for overcoming driver inattention is to remove the driver completely from the system. This can be accomplished by an automated highway. In a 1982 study performed for the FHWA ("Systems Studies of Automated Highway Systems"), the various candidate system concepts were evaluated for application in the 1990 to 2000 time-frame. The study results recommended a system with an "intelligent" vehicle (radar and electronically equipped) with a self-contained power supply (engine) operating on a passive guideway. They estimated that, if development and testing started in 1982, the prototype system would be completed in 1995 and a "Phase 2" urban system in 2010. In our estimation, it would appear that the automated highway system could have no major impact on highway safety before the middle of the 21st century.

4.5 AUTOMOTIVE ELECTRONICS

Electronics for automobiles has taken a tremendous leap forward in the past ten years. This progress was driven by the need for engine control microprocessor systems for improved fuel economy, greater performance, and improved emission control. The cost of the electronics contained in the average U.S. vehicle increased from $25 to $250 between 1970 and 1980, and could reach as high as $1400 by 1990. Sixteen bit microprocessors with 2MHz frequency will soon be available with programmable memories. Voice synthesis and driver visual aids are available and will be expanded in the near future. Voice recognition and synthesis will contribute to a safer driving environment by allowing the driver to concentrate on road conditions. An important next step in automotive electronic development will be the use of multiplexed systems and fiber optics to eliminate complex wiring. Such an advancement will allow the easy addition of extra electronic equipment (such as aftermarket driver monitors). The existing electronic systems and the near-term projected advancements lead us to conclude that the electronics will be available to reliably track and analyze any practical driver alertness monitor

5.0 CONCLUSIONS

The material reviewed in this document indicates the following:

5.1 ACCIDENT DATA

- The fact that a large portion (38%) of drivers involved in automobile crashes, as reported in the 1982 NASS file, took no action to avoid the collision suggests that attentional lapses are a major factor in the causation of highway accidents.

5.2 RESEARCH FINDINGS

- Changes in performance associated with task duration and or/drowsiness include: a reduction of the frequency of control responses, periodic "blockage" of all responses, an increase in the amplitude of responses, and an increase in the variability of the responses
- In controlled experiments, averaging across subjects who are exposed to the same conditions, there are reliable changes in performance which are monotonically related to attentional state.
- Examination of the performance of the individuals in these studies indicates that while performance of selected tasks decreases with degraded attention the relationship between the changes in performance and the attentional state varies significantly between the subjects.
- The use of multiple performance indices will enhance the discriminative power of the attentional discrimination system.
- Although performance changes can reliably reflect modifications in attentional state, the most difficult problem in detecting degraded

alertness will be discriminating the effect of these changes from those imposed by the driving environment.

5.3 DRIVER ALERTNESS SYSTEMS

- Proprietary alertness indicators fall into two functional classes: those which evaluate performance and those which evaluate the physical or physiological state of the subject.
- Indicators that are based on physiological or physical concomitants of attention are likely to be too cumbersome to achieve widespread use by private vehicle operators.
- Indicators that are based on the performance of a secondary task are likely to be distracting to the driver and, therefore, potentially hazardous.
- A driver attention indicator must be able to "learn" the shape of the performance change curves particular to the individual driver.
- Of the proprietary devices reviewed, only the Nissan Safety Drive Alert System, which is based on a multivariable analysis approach and learns the patterns of the individual driver, represents a potentially promising approach.
- The existing electronic systems and the near-term projected advancements lead us to conclude that the electronics will be available to reliably track and analyze any practical driver alertness monitor.

6.0 RECOMMENDATIONS

Based on the material reviewed to date, it is concluded that a research effort to experimentally investigate the efficacy of a multivariate technique for monitoring driver attention should be undertaken. The results of this preliminary study have shown that a significant number of vehicular accidents are associated with the failure of the driver to respond to external stimuli, indicating reduced alertness. A research effort is proposed to identify and determine the most effective techniques for monitoring driver attention and advising the driver of critical degradations in attentional state.

The research program would require both a laboratory simulation phase and a field testing phase. The laboratory testing would involve the use of "part-task-simulation". The purpose would be to investigate idiosyncratic changes in driver performance as a function of attentional state. The results of the laboratory testing will provide basis for the development of performance criteria which can be evaluated under real-world conditions in the field testing phase.

6.1 SIMULATION PHASE

The purpose of this phase will be to develop a set of descriptive metrics for changes in performance associated with:

- Time-on-task,
- Sleep deprivation,
- Task requirements, and
- Stimulus environment complexity.

In this phase, subjects (stratified by age and sex) would be trained on compensatory tracking tasks. Performance would be evaluated in terms of response frequency, consistency, and accuracy. Subjects would be trained on the tasks until a performance plateau was reached and then tested repeatedly to determine criteria for measuring performance changes due to attentional lapses. These changes would be correlated with physiological indices of attention such as EEG and eye movement patterns.

6.2 FIELD TEST PHASE

If criteria for evaluating performance shifts within individuals are successfully developed, then these criteria would be evaluated and validated through on-road testing. Road testing would be required for the following reasons:

- Only those performances that are integral parts of the driving task, such as steering, braking, and velocity control can be used. The addition of other tasks which require frequent responses could be distractive and thereby hazardous.
- Tests to evaluate and validate measures of attentional change must occur in a naturalistic environment with appropriate visual, auditory, and motion cues. There exist no simulation facilities that can provide the required environments.
- The evaluation and validation of the measures must be imbedded in other credible road testing efforts, such as tire testing or vehicle testing, to minimize the possibility of the driver's attentional state being influenced by the attentional testing itself.
- The field testing will be an iterative development/evaluation effort, rather than a series of classic experiments.
- Field testing would provide an opportunity for evaluating proprietary devices.

APPENDIX A

1982 NASS DATA TABLES 1-6

TABLE 1

DRIVER RESPONSES IN ALL COLLISION ACCIDENTS

Vehicle Role -------	STRIKING				STRUCK				ALL	ALL			ALL		
Driver Action -------	NOTHING		ACTION		NOTHING		ACTION		ALL	NOTHING			ACTION		
	#	%	#	%	#	%	#	%	#	#	%	%	#	%	%
age<25	905	34	2457	42	478	26	456	31	4296	1383	31.	32	2913	40.	68
25-55	1331	50	2859	48	985	54	786	54	5961	2316	51.	39	3645	49.	61
> 55	429	16	600	10	375	20	207	14	1611	804	18.	50	807	11.	50
Sum of All Collisions	2665	22.	5916	50.	1838	15.	1449	12.	11868	4503		38.	7365		62.
Land use -urban	2077	78	4436	75	1531	83	1194	82	9238	3608	80.	39	5630	76.	61
rural	588	22	1479	25	307	17	255	18	2629	895	20.	34	1734	24.	66
Time Period -Early Am	433	16	899	15	139	8	123	9	1594	572	13.	36	1022	14.	64
Am Rush	399	15	762	13	264	14	209	14	1634	663	15.	41	971	13.	59
Mid Day	878	33	1768	30	711	39	551	38	3908	1589	35.	41	2319	32.	59
Pm Rush	472	18	1152	20	410	22	307	21	2341	882	20.	38	1459	20.	62
Evening	470	18	1282	22	310	17	252	17	2314	780	17.	34	1534	21.	66
Road alignment -Straight	2224	84	4659	79	1636	89	1231	85	9750	3860	86.	40	5890	80.	60
Curved	438	16	1239	21	201	11	211	15	2089	639	14.	31	1450	20.	69
Occupant # -One	1932	72	4078	69	1116	61	945	65	8071	3048	68.	38	5023	68.	62
> One	733	28	1838	31	722	39	504	35	3797	1455	32.	38	2342	32.	62
Vehicle Role	STRIKING				STRUCK				ALL	ALL			ALL		
Driver Action	NONE		AVOID		NONE		AVOID		ALL	NONE			AVOID		
	# DRI	%	# DRI	%	# DRI	%	# DRI	%	# DRI	# DRI	%	%	# DRI	%	%

TABLE 2

DRIVER FACTORS INATTENTIVE SPEED >0.5mph																		all dri-fact	
Vehicle role		Striking				Struck				collision only								collision only	
Driver Action		NOTHING		Yes		None		Yes		Sum		Sum			Sum			Sum	inatter
			%		%		%		%	Drivers	%	No act	%	%	action	%	%	Drivers	%
age	<25	106	36	224	44	31	38	20	31	381	40	137	36	37	244	64	43	4296	9
	25-55	143	48	239	46	30	37	32	50	444	46	173	39	46	271	61	47	5961	7
	> 55	44	15	46	9	19	23	12	18	121	12	63	52	17	58	48	10	1611	8
Land use -	urban	217	74	350	68	62	77	47	73	676	71	279	41	75	397	59	69	9238	7
	rural	76	25	159	31	18	22	17	26	270	28	94	35	25	176	65	31	2629	10
Time Period -	Early Am	34	11	80	15	6	5	1	50	121	13	40	33	11	81	67	16	1594	8
	Am Rush	62	21	68	13	16	6		0	146	16	78	53	21	68	47	13	1634	9
	Mid Day	97	33	150	29	30	31		0	277	31	127	46	34	150	54	30	3908	7
	Pm Rush	45	15	91	18	14	12		0	150	17	59	39	16	91	61	18	2341	6
	Evening	54	18	113	22	14	9	1	50	182	20	68	37	18	114	63	23	2314	8
Road alignment	Straight	250	85	422	83	71	56	2	100	745	84	321	43	86	424	57	83	9750	8
	Curved	43	14	85	16	9	8		0	137	15	52	38	14	85	62	17	2089	7
Occupant # -	One	208	70	362	71	57	48	2	100	629	71	265	42	71	364	58	71	8071	8
	> One	85	29	147	28	23	13		0	255	28	108	42	29	147	58	29	3797	7
		293	100	509	100	80	100	2	100	884	100	373	42	100	511	58	100	11868	7

TABLE 3

DRIVER FACTORS - DROWSY SPEED >.05mph COLLISION ONLY

Vehicle role ------		Striking				Struck				ALL		ALL			ALL			all dri-fact collision only	
Driver Action ------		NOTHING		ACTION		NOTHING		ACTION		ALL		NOTHING			ACTION			Sum	drow/all
		#	%	#	%	#	%	#	%	#	%	#	%	%	#	%	%	#	%
age	<25	60	57	30	45	1	25	1	50	92	100	61	66	56	31	34	46	4296	2
	25-55	39	37	30	45	3	75	1	50	73	79	42	58	39	31	42	46	5961	1
	> 55	5	4	6	9		0		0	11	11	5	45	5	6	55	9	1611	1
All																			
Land use -	urban	51	49	29	43	2	50	1	50	83	90	53	64	49	30	36	44	9238	1
	rural	53	50	37	56	2	50	1	50	93	101	55	59	51	38	41	56	2629	4
Time Period -	Early Am	64	61	37	57	1	20	1	50	103	111	65	63	60	38	37	58	1594	6
	Am Rush	21	20	8	12		0		0	29	31	21	72	19	8	28	12	1634	2
	Mid Day	5	4	6	9		0		0	11	11	5	45	5	6	55	9	3908	0
	Pm Rush	4	3	5	7	2	40		0	11	11	6	55	6	5	45	8	2341	0
	Evening	10	9	8	12	2	40	1	50	21	22	12	57	11	9	43	14	2314	1
Road alignment	Straight	76	73	48	72	3	75	2	100	129	140	79	61	73	50	39	74	9750	1
	Curved	28	26	18	27	1	25		0	47	51	29	62	27	18	38	26	2089	2
Occupant # -	One	90	86	46	74	1	25	2	100	139	151	91	65	84	48	35	75	8071	2
	> One	14	13	16	25	3	75		0	33	35	17	52	16	16	48	25	3797	1

TABLE 4

Driver Factors Drunk >.07%bac > 0.5mph																		all dri-fact	
Vehicle role -------		STRIKING				STRUCK				ALL		ALL			ALL			collision only	
Driver Action -------		NOTHING		ACTION		NOTHING		ACTION		ALL		NOTHING			ACTION		Sum		drnk/all
		#	%	#	%	#	%	#	%	#	%	#	%	%	#	%	%	Drivers	%
age	<25	66	42	78	40	4	36	4	30	152	40	70	46	42	82	54	39	4296	4
	25–55	83	52	105	53	5	45	7	53	200	53	88	44	52	112	56	54	5961	3
	> 55	8	5	12	6	2	18	2	15	24	6	10	42	6	14	58	7	1611	1
All																			
Land use –	urban	101	64.	126	65.	8	72	10	76	245	65	109	44	65	136	56	65	9238	3
	rural	56	36.	69	35.	3	27	3	23	131	34	59	45	35	72	55	35	2629	5
Time Period –	Early Am	74	48	83	43	5	5	6	46	168	45	79	47	48	89	53	43	1594	11
	Am Rush	0	0	3	1	1	6		0	4	1	1	25	1	3	75	1	1634	0
	Mid Day	8	5	14	7	1	31	1	7	24	6	9	38	5	15	63	7	3908	1
	Pm Rush	14	9	26	13	2	12	2	15	44	11	16	36	10	28	64	14	2341	2
	Evening	58	37	66	34	2	9	4	30	130	35	60	46	36	70	54	34	2314	6
Road alignment	Straight	117	74	140	71	9	56	10	76	276	73	126	46	75	150	54	72	9750	3
	Curved	40	25	55	28	2	8	3	23	100	26	42	42	25	58	58	28	2089	5
Occupant # –	One	112	71	142	72	8	48	6	46	268	71	120	45	71	148	55	71	8071	3
	> One	45	28	53	27	3	13	7	53	108	28	48	44	29	60	56	29	3797	3

TABLE 5

DRIVER FACTOR – MEDICATION Vehicle role Driver Action		SPEED > 0.5mph Striking NOTHING #	%	ACTION	%	COLLISION ONLY Struck NOTHING #	ACTION %	ALL ALL #	%	ALL NOTHING #	%	%	ALL ACTION #	%	%	all dri-fact collision only Sum #	med /all %
age	<25	0	0	1	16	0	0	1	10	0	0	0	1	100	17	4296	0
	25–55	4	100	3	50	0	0	7	70	4	57	100	3	43	50	5961	0
	> 55	0	0	2	33	0	0	2	20	0	0	0	2	100	33	1611	0
Land use –	urban	4	100	5	83	0	0	9	90	4	44	100	5	56	83	9238	0
	rural	0	0	1	16	0	0	1	10	0	0	0	1	100	17	2629	0
Time Period –	Early Am	1	33	2	33	0	0	3	33	1	33	33	2	67	33	1594	0
	Am Rush	1	33	1	16	0	0	2	22	1	50	33	1	50	17	1634	0
	Mid Day	1	33	1	16	0	0	2	22	1	50	33	1	50	17	3908	0
	Pm Rush	0	0	0	0	0	0	0	0	0		0	0		0	2341	0
	Evening	0	0	2	33	0	0	2	22	0	0	0	2	100	33	2314	0
Road alignment	Straight	4	100	2	100	0	0	6	100	4	67	100	2	33	100	9750	0
	Curved	0	0	0	0	0	0	0	0	0		0	0		0	2089	0
Occupant # –	One	112	71	2	100	8	6	128	69	120	94	71	8	6	53	8071	2
	> One	45	28	0	0	3	7	55	30	48	87	29	7	13	47	3797	1

TABLE 6

DRIVER FACTORS - ILLEGAL DRUG SPEED > 0.5mph all dri-fact
Vehicle role - (Striking only - No Struck Cases Found)

Driver Action ------		NOTHING #	NOTHING %	ACTION #	ACTION %	BOTH #	BOTH %	ALL COLLISION #	drg/all %
age	<25	2	25	7	70	9	50	4296	0
	25-55	6	75	3	30	9	50	5961	0
	> 55	0	0	0	0	0	0	1611	0
Land use -	urban	7	87	7	70	14	77	9238	0
	rural	1	12	3	30	4	22	2629	0
Time Period -	Early Am	4	50	3	30	7	38	1594	0
	Am Rush	0	0	1	10	1	5	1634	0
	Mid Day	1	12	1	10	2	11	3908	0
	Pm Rush	0	0	1	10	1	5	2341	0
	Evening	3	37	4	40	7	38	2314	0
Road alignment	Straight	6	75	7	70	13	72	9750	0
	Curved	2	25	3	30	5	27	2089	0
Occupant # -	One	6	75	7	70	13	72	8071	0
	> One	2	25	3	30	5	27	3797	0

APPENDIX B

A BRIEF REVIEW OF METHODOLOGIES REQUIRED FOR A MODEL BASED APPROACH TO DRIVER INATTENTION DETECTION

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Massachusetts Institute of Technology

February 1, 1984

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I. Introduction

This brief report summarizes the current state of the art in the methodologies and hardware required for a model based approach to driver inattention. The report is subdivided into sections describing:

- Human operator models
- System failure detection models
- Parameter estimation from measurements
- Vehicle instrumentation

The proposed approach involves postulating a driver steering model, e.g. the frequency domain cross-over model, the parameters of this model would be estimated from the vehicle measurements by parameter identification algorithms, e.g. the maximum likelihood method. A "failure", i.e. erratic driver performance, would be identified by using failure detection methods. All of the methodologies required, i.e., driver modelling, vehicle instrumentation, parameter estimation and failure detection have been developed for application to other fields and well documented software exists for their implementation.

This report summarizes most of the pertinent literature.

II. Operator Models

1. Background

Human operator control behavior can be characterized by the responses to certain types of disturbances: one step further is to give the relation between the disturbance and the operator's response. This relation then is a model of the operator's control behavior. There are two possible ways to formulate a model, leading to either a descriptive model or a normative model. A descriptive model is a description of an input-output relation, as found from experimental data, for a given set of task variables. A normative model describes, based on a given theory, what the input-output relation should be as a function of the task variables. In many cases development of a model starts with the formulation of one or more descriptive models. These models, in fact, represent a condensed version of an experimental data base. They are primarily a tool for data reduction. A more fundamental step will be the formulation of a theory, which leads to a normative model which can be tested on the available data. If this test is positive, predictions are made for new situations. If these predictions are correct, the model is valid for the type of applications for which it is designed.

2. Models of Driver Steering Control

Models have been applied in the automotive field may be categorized as 1) Quasi-linear, 2) Predictive, 3) Optimal Control, 4) Information Processing.

1) Quasi-linear Models - A summary of this model and its basis is given by McRuer and Krendel [6]. The "crossover" model as described in [6] has been used to model drive steering control and to determine

the most likely loop closures used by the driver. The outer loop is control of lateral position which is needed to satisfy the basic guidance and control requirement for precision path following. This loop by itself is unstable. Stability can be provided either by generating low frequency lead in the lateral deviation feedback loop or by using other inner perceptual feedback loops. In this work a number of possible multi-loop structures have been considered. The most developed form is that presented in [7], which has been experimentally validated in a simulator [7] and to a limited extent in real driving [8]. The experiments of Shaw [9] also support the analytical work of McRuer and Weir.

QUASI-LINEAR CROSSOVER MODEL

by: Weir and McRuer [7], 1973

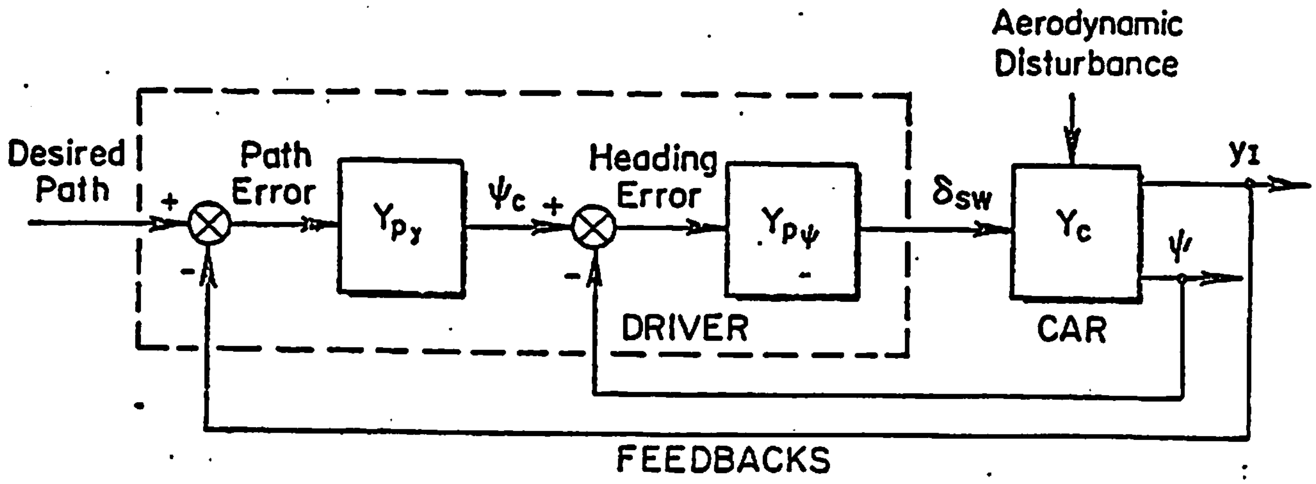


Figure 1. Driver/Vehicle System Structure for Analyses

Y_c = Vehicle Dynamics and Display Simulation

$Y_{p\psi}$ = Driver Operations of Functions of Heading

Y_{py} = Driver Operations on Functions of Position Error

δ_{sw} = Steer Angle

Y_I = Lateral Position

Ψ = Heading Angle

τ_ψ = Driver Time Delay in Heading Control

K_ψ = Driver Gain for Heading Control

K_y = Driver Gain for Lateral Position Control

$$Y_{p\psi} = K_\psi e^{-\tau_\psi jw}$$

$$Y_{py} = K_y$$

2) Predictive Models - Kondo and Ajimine [10] assumed that the lateral deviation of the drivers sight point from the predetermined course is his input cue for steering control. Yoshimoto [11] postulated a model in which the input cue was the lateral deviation from the course of the predicted position of the vehicle in a given prediction time. These models are all single loop models but each has different input cues.

3) Optimal Control Models - The describing function model is adequate for lane-keeping type tasks. But in situations where course planning and other forms of maneuver are required an "optimal control" type of model may be more appropriate. Such a model has been outlined by Roland and Sheridan [12] and [13], but very few experimental results have been reported. The central problem with this type of model is in determining the driver's cost weighting.

4) Information Processing Models - Crossman and Szostak [14] proposed a digital-type information processing model with continuous control models describing the different stages within the model. The model is conceptually similar to that of Weir and McRuer and includes an open loop model of control using preview.

3. Empirical Steering Control Models

Weirwille, Gagne and Knight [15] obtained data in a simulator in which the dynamics were those for lateral position control of a vehicle. But without heading control dynamics, Weir and Wojcik [16], Weir and McRuer [7] and McRuer and Klein [8] have reported data for simulators having heading angle and lateral position inputs. All found agreement with theoretical models. As noted previously data obtained from real vehicles [9] and [8] also agree with the Quasi-Linear Models.

Garrot, Wilson, and Scott (1982) successfully implemented four computer models of drivers (two of the models using describing function, and the other two using preview predictor strategies) in conjunction with a recently developed, all digital vehicle simulation. They compared the results of both class of models [17], and concluded that:

1. All of the driver models performed acceptably in the wind gust maneuver.
2. For the double lane change maneuver, both the three degree of freedom preview predictor model and the general path describing function model performed in an acceptable manner. The preview predictor model's simulated trajectory was closer to the desired path than was that of the describing function model, with the preview predictor model having less overshoot and a smaller

time lag. This is due to the inherent lack of driver "look ahead" in the describing function model.

This study found several practical difficulties that will complicate validating the preview predictor driver model. These difficulties involve the driver parameters that are used by these models. First of all, these models use a large number (30) of driver parameters compared to the six used by the describing function models. This makes it far more difficult to determine parameter values from experimental data. A major drawback of the describing function models is their lack of driver "look ahead". However, this could be added to the model by means of a feed foward look. This, in their judgement, makes the describing function formulation the preferred one for further research in this area.

4. Compensatory, Pursuit, Preview, and Precognitive Control

Manual-control systems classification according to the nature of the input to the Human Operator [5].

1) Compensatory system
2) Pursuit System
3) Preview System
4) Precognitive System

1) A compensatory system, is one in which the human operator has a single input, the error e, the difference between actual system response y and the ideal response (the reference input).

2) A pursuit system, is one in which the instantaneous reference input r and instantaneous controlled process output y are both displayed to the human operator separately and independantly, so that he may distinguish individual properties of these signals by direct observation.

3) A preview system, is similar to the pursuit system except that the human operator has available a true display of reference input, (r(t) from the present time until some time into the future.

4) A precognitive system, is one in which the operator has foreknowledge of the input in terms other than a direct and true view. Qualitatively, one can think of the operator as possessing a map of the road ahead and a memory for what has occurred before, and having a battery of responses programmed and ready for execution.

III. System Failure Detection

1. Background

Failure is any change which reduces a system's effectiveness. This change may take the form of a component failure, a variation in a system parameter, or a variation in the operating environment. There are two general categories of computerized failure detection methods:

A. Comparing the system with a series of models presenting possible failure modes of the system.

B. Comparing the system with a single model of the system's normal operation mode.

in "A" a failure is detected when the measured system outputs match their corresponding calculated variables of one of the models. But, in "B" a failure is detected when the measured system outputs and their corresponding model variables do not match.

The necessity to preprogram the possible system failure modes is the limitation of method "A". This is true especially if there are many possible failure modes, which cannot practically be considered. The unconsidered failure modes are not detectable by this class of methods.

In method "B" all system failures which result in significant deviations between the system and model outputs will be detected. However, the cause of these failures are not locatable unless the system model setup is modified. This is true because a system failure will, in general, cause a system-model disparity of many outputs. Sheridan [20] have proposed a way to obtain the location capability of the methods included in this category. He proposed to break the aggregated model into submodels, each of which is forced by the appropriate system measured variables. The outputs of these submodels are compared with their corresponding system outputs. A deviation of the outputs of any submodel indicates that its corresponding subsystem has failed. The disadvantage of this method is that it does not specify the compared system-model outputs. In practice, only a partial set of the many system-model outputs is compared. Tsach [21] has shown that a chosen set of outputs does not necessarily detect all possible system failures. Therefore, a method that detects and locates system failures by utilizing a single reference model specifying the compared system-model outputs seems to be required.

He developed a computerized method to detect failures and to locate the causes in real-time. His method is called Failure Detection and Location Method (FDLM). Failures are detected when the differences between the measured systems' power variables and their corresponding calculated model values, be outside preset limits. The causes are located by disaggregating the model and utilizing the causal description of the resultant submodels. This method eliminates the necessity to preprogram the system's possible failure modes, but requires an efficient failure location procedure. System, sensor, and control input failures can be identified by FDLM. The display interfacing FDLM to the human operator was designed to minimize the rate of missings and false alarms and the operator's reaction time. He also applied a simulation test of FDLM to a part of a ship's engine to demonstrate the advantages of the method.

2. Reference Model Approach

The reference model approach developed by Jones, H. L. [18] provides a general capability for real-time failure detection and identification in continuous, stochastic, time invariant systems with continuous measurements. A simple approximation extends the approach to stochastic systems with discrete measurements. The approach requires that an accurate model of the unfailed system dynamics be known. For a system with m sensors, a failure detection system is defined which can detect and identify failures in at least m different system components. The failure detection and identification are independent of the manner in which a component fails as long as the failure alters the system output.

The central issue of [18] is detection of events that result in the degradation of the system's performance below some threshold value, and identification of the associated failures in an on-line basis. The event may be either a sudden or a gradual failure.

IV. System Identification

1. Background

System identification, according to Zadch [22], is the determination on the basis of input and output, of a system within a specified class of systems, to which the system under test is equivalent. Identification, therefore, starts with the specification of a class of systems, that is the structure of a model, and the choice of a criterion for equivalence.

Identification methods can be divided into non-parametric methods, such as the estimation of impulse responses or of transfer functions, and in methods aimed at the estimation of unknown parameters in a model with a given structure. Non-parametric methods are applied when no apriori knowledge on the model structure is available. If some knowledge is available on the structure a method which makes use of this knowledge may lead to a more efficient way of data reduction.

2. Parameter Estimation

Parameter estimation is a description for a number of identification methods which all fit the following definition, "parameter estimation is the experimental determination of values of parameters that govern the dynamic behavior of a system, assuming that the structure of the system is known". The choice of a certain method and its usefulness will depend on a number of aspects. Here, an overview will be given of these aspects.

The first aspect to be considered is the type of system and, consequently, that of the model. An important point is the choice of the system boundaries. In some cases, for instance, it is required to model also the shaping filter of the system noise, in order to obtain meaningful results, whereas this is not necessary in other cases. For systems in a closed loop, sometimes the whole closed loop system is modelled.

The second aspect is the criterion for equivalence between system and model. A general requirement for a criterion is that it should be concave with a minimum or, equivalently convex with a maximum, at the desired value of the parameters. The criterion determines to a great extent the method. Well-known criterion are the Maximum Likelihood, and the Weighed Least Square Error. In fact, for normally distributed signals, the weighed least square error criterion can be considered as a special case of the maximum likelihood criterion. The main reason to choose a least squared error criterion is to obtain a set of linear equations for the parameters. When a least squared error criterion is applied, it is of importance which quantity is chosen as the error to be minimized. This will mainly depend on the structure of the model. For a linear regression model the error is the difference between system output and model output. In a generalized model another quantity has to be chosen in order to obtain a set of linear equations.

The experimental conditions form another aspect. These conditions concern:

- The loop configuration, open or closed.
- The input; natural fluctuations resulting from the system noise, with or without an additional forcing function introduced by the experimenter.
- The observation time. In practical applications this time cannot

be chosen arbitrarily long. In conjunction with the signal to noise ratio of the observed signals it poses a limit on the accuracy of the estimated parameters.

3. Program Packages for Process Identification

Program packages for process identification have been developed which are complete sets of programs according to the various steps of an identification procedure.

(A) Program packages for general digital computer applications in off-line (batch) operation

(B) Program packages for process computer applications in on-line (real time) operation.

Packages of type (A) consist of, for example, data filtering, one or several methods for identification and parameter estimation, methods for search of model order, model verification and proper graphic presentation of the results. Packages of type (B) consist of the same items, but in addition have to take into account real-time execution, process dependent interrupts, foreground and background organization, use of internal and external storages, and signal generations.

During the 4th IFAC-Symposium on Identification and System Parameter Estimation in Tbilisi, 21-27 September, 1976, a round table was held on these program packages. As a result 21 program packages have been described and the main results can be summarized as follows:

For all 21 packages a high level programming language was used, mostly FORTRAN, but also ALGOL and PL/1. Of these, 12 packages are written for process computers and nine for general purpose digital computers. In all cases linear processes can be identified, nonlinear processes in nine cases (mostly linear in parameters) and time-variant processes in eight cases (mostly slowly time varying). As process and noise models differential equations or s-transfer functions or vector differential equations, difference equations of z-transfer functions or impulse responses are used. Hence, most of the authors regarded discrete-time models. As well as single-input as multi-input-single-output as multi-input-multi-output processes are taken into account. The packages furthermore distinguish in the applied identification and parameter estimation methods, recursive or nonrecursive algorithms, ranges of model order and time delay, methods for search of model order, drift elimination and model verification and final results. The required computer storage ranges from 20 to 1.000K on the disk, however with the smaller modules 2 and 256K required in the core memory.

APPENDIX C

Alertness Indicators

There have been several devices developed as indicators of driver alertness. The following brochures depict the operation of the:

1. Reli "Stay-A-Wake"
2. Slarner "Driver Alert Warning Device"
3. Nissan "Safety Drive Advisor"
4. Life Technology Inc./Ford "Owl"
5. Safex "Drive Alert"

Appendix C (Con't)

Reli "Stay-A-Wake"

LIABILITY STATEMENT:

Stay-A-Wake is designed and manufactured as a safety alarm to be used by the vehicle operator at their discretion to aid driver alertness. Reli Corporation assumes no responsibility or liability for the driver, passengers, vehicle or property associated with the Stay-A-Wake alarm. This product in no way relieves or reduces the responsibility of the driver to maintain his powered vehicle under safe and proper control during all conditions.

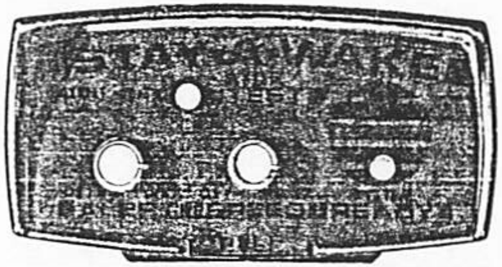
LIMITED WARRANTY STATEMENT:

We guarantee our equipment when properly installed to be free from defect in material and workmanship under normal use and service, and we will, within 90 days from delivery to original purchase, repair or replace without cost to the owner, any part or portion thereof which our inspection proves to be defective (if and when returned to us) with proof of purchase – within 90 days to: Reli Corp., P.O. Box 393, Markle, Indiana 46729, or any Reli Corp. authorized factory service center, transportation charges prepaid and only defective unit returned.

This guarantee does not apply to equipment which has been subjected to misuse, neglect, accident, or exposure to the elements, and is in lieu of all guarantees expressed or implied, and we do not authorize any person or representative to assume for us any other liabilities with our products.

Reli Corporation expressly disclaims any express or implied warranties or liabilities that its equipment will be fit for any particular purpose and any other expressed or implied warranties or liabilities other than those specifically set forth herein, including without limitation any warranty or merchantability.

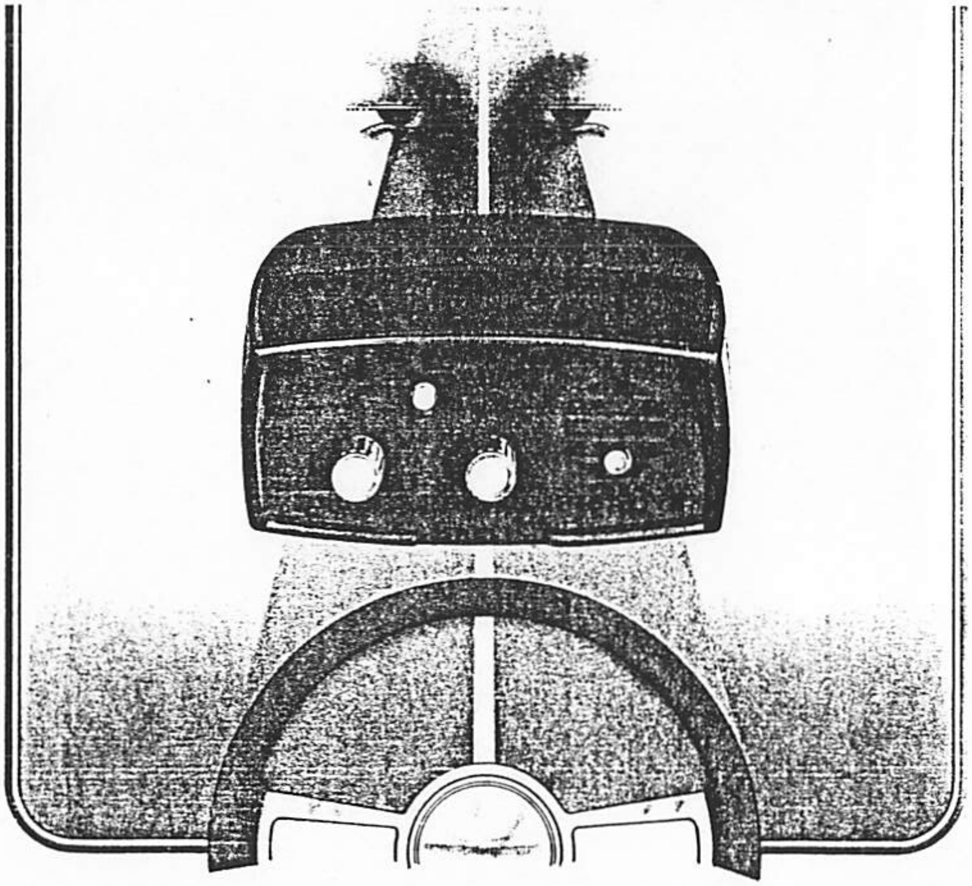
Unless installation instructions are followed exactly, the manufacturer will not be responsible for damage or defect.



STAY-A-WAKE
RELI CORPORATION
P. O. BOX 393
MARKLE, IN 46770

ON THE ROAD WE CAN HELP YOU

STAY-A-WAKE™



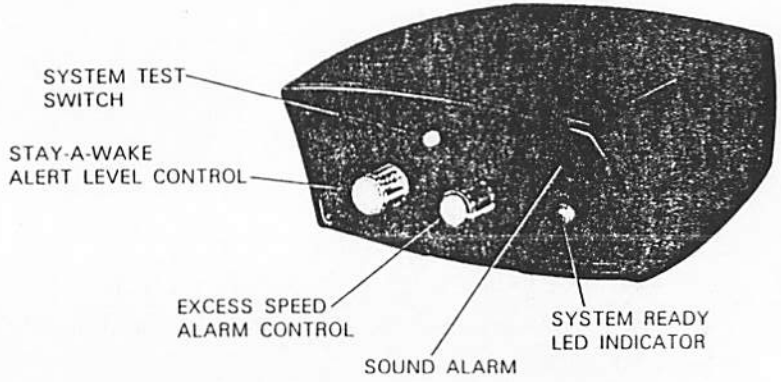
STAY-A-WAKE

ELECTRONIC SAFETY COMPANION THAT NEVER SLEEPS!

Stay-A-Wake electronically monitors driver alertness along with vehicle speed and "sounds off" when conditions are unsafe. Driver alertness is determined by sensing steering corrections, comparing these corrections at the vehicles speed over a preset time period. Normal steering corrections required for proper and safe vehicle control provides an excellent indicator of driver alertness. Altered or sudden changes in steering corrections, preceed and can forewarn driver drowsiness, sleepiness or road hypnosis due to prolonged driving.

STAY-A-WAKE FEATURES:

- Detects driver sleepiness
- Warns against excessive speeds
- Attention getting warning alarm
- Fully automatic, adjusting required alertness at driving speed
- Test switch for system check out
- System functioning L.E.D. Indicator
- Adjustable alertness level for varying driving and road conditions
- Remote switching output for Cruise Control (defeats upon alarm)
- Optical steering correction sensor (no mechanical steering wheel contact)
- Velcro hook and loop fastener for dashboard mounting
- Solid state integrated circuit reliability
- Simple to use – Easy to install
- Universal – Will work with all American made vehicles and most foreign models

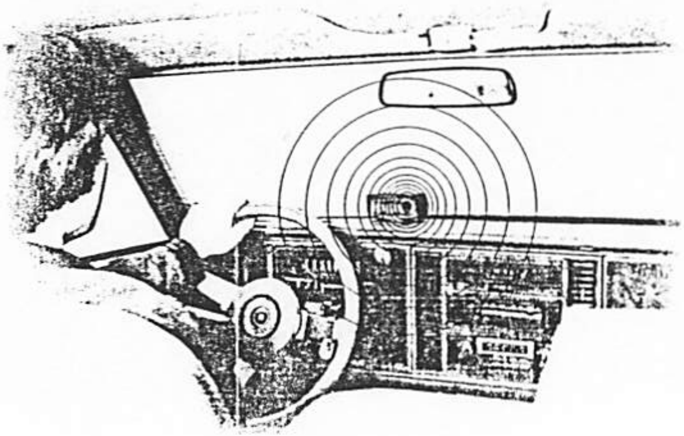


Stay-A-Wake a fully automatic safety alarm actuates itself at 15 MPH and constantly monitors your driving alertness by analyzing steering corrections at the vehicles speed over a preset time interval. Once the level of desired driver alertness is programmed into the Stay-A-Wake alarm any reduction in driver alertness will signal the alarm to "sound off" and defeat the Cruise Control if interconnected.

Another safety monitoring feature of the Stay-A-Wake is an excess-over-speed alarm which alerts the driver when the preset maximum speed has been exceeded.

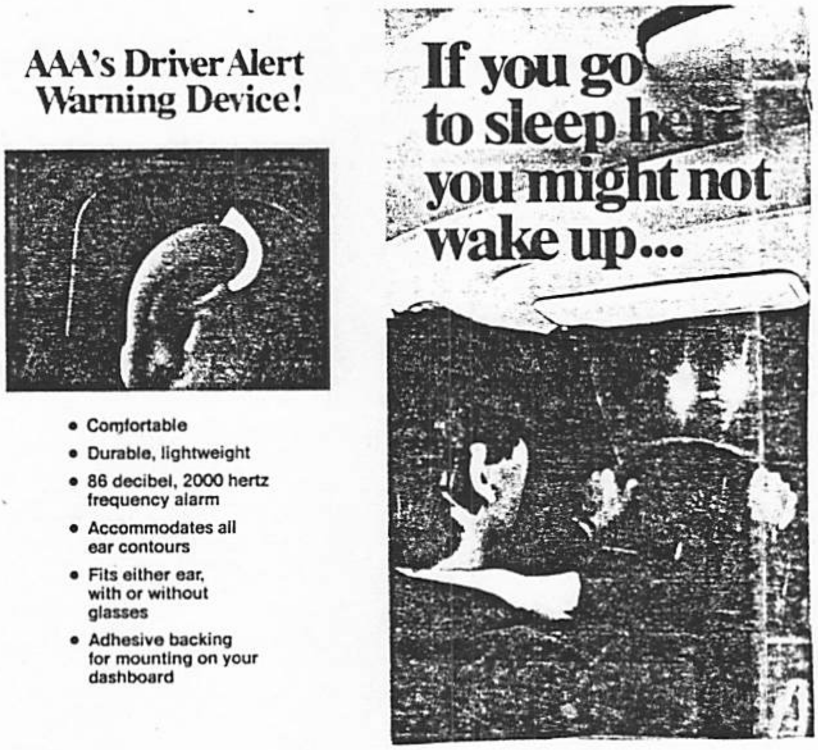
Stay-A-Wake alertness level along with maximum vehicle speed alarms are easily adjustable and can be set to accommodate all driving and highway conditions – no annoying nuisance false alarms. Each alarm can be independently adjusted and turned off if desired.

Stay-A-Wake alarm is complete with system test switch which permits total system check out prior to actual driving. A solid state L.E.D. light comes on when the Stay-A-Wake is functional and monitoring driver alertness. Stay-A-Wake automatically adjusts the level of driver alertness required for safe driving at all vehicle speeds above 15 MPH.



PATENT PENDING

Slarner "Driver Alert Warning Device"



AAA's Driver Alert Warning Device!

- Comfortable
- Durable, lightweight
- 86 decibel, 2000 hertz frequency alarm
- Accommodates all ear contours
- Fits either ear, with or without glasses
- Adhesive backing for mounting on your dashboard

Guard against falling asleep at the wheel with AAA's Driver Alert Warning Device!

Help guard against falling asleep at the wheel with AAA's new Driver Alert Warning device. The Driver Alert is designed to signal an individual that they have started to dose off—rest is needed—it's dangerous to continue driving.

The shape of this durable, lightweight (15 grams including the 1.5V battery) device provides comfort and ensures transmission and amplification of an 86 decibel, 2000 hertz frequency alarm when any of its 18 pre-selected positions is surpassed by a nod of the driver's head.

Designed to accommodate all ear contours, the Driver Alert can be worn on either ear regardless of whether you wear glasses or not. The device comes in a convenient storage box with adhesive backing for quick and easy mounting on your car's dashboard.

A $32.95 Value!

AAA member price only $21.00 each, or 2 for $40.95. Non-members add $5.00 per warning device.

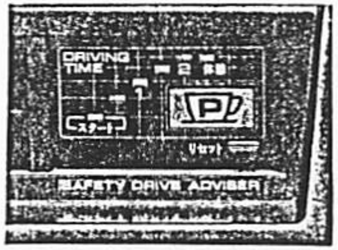
Appendix C (Con't)

Nissan "Safety Drive Advisor"

This is a copy of an article from the January 1984 SAE *Automotive Engineering*.

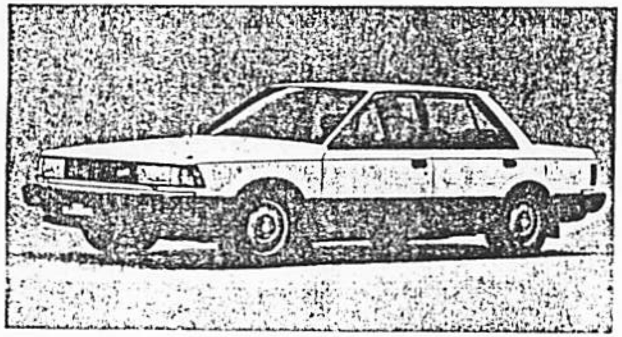
Onboard electronic adviser warns of erratic steering behavior

SDA, safety drive adviser, is one of many electronic devices Nissan had built into its experimental safety vehicle, the NRV (Nissan Research Vehicle), which are now being offered on top models in the recently updated Bluebird mid-size car range. SDA, as first introduced in the NRV, had a singular function of warning the driver of erratic steering behavior. To this, Nissan has added a timing device that displays an elapsed driving time by a row of incremental lamps, and advises of a timely stretch-out break by lighting up a "coffee cup" display lamp and sounding a buzzer, which the system judges at two hours after departure on a clear daylight condition. Should the driver ignore the advice, and push on, the system issues a buzzer warning every hour thereafter. If the driver heeds to the system's wisdom, it allows four times the actual rest time (ignition key off, or the car stays stationary with the engine running for more than five minutes) to the next increment of elapsed driving time, delaying advice time. For night driving and inclement weather with wipers on, the system shortens information and advice intervals, for each deducting ten per cent. So driving in rain at night, the system issues a "better-take-a-cup" advice at one hour 36 minutes plus ATD.

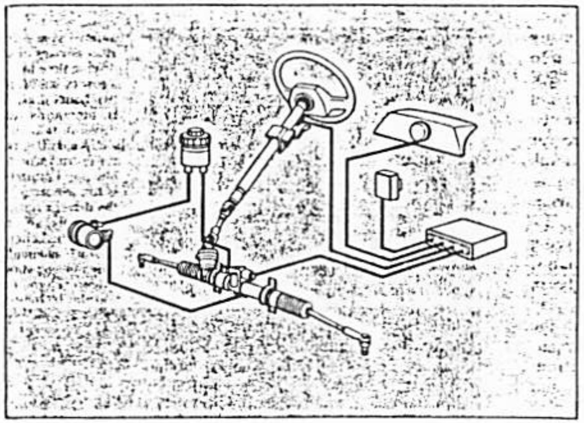


Safety Drive Adviser advises of elapsed driving time by a row of lamps, and at two hours plus, recommends that the driver rests with a cup of coffee or tea. Its more important and imminent task is to memorize the driver's normal steering habits, and detect any erratic behavior such as encountered when he/she should fall asleep. Then it issues warning by lighting up the cup lamp and sounding alarm buzzer.

SDA's more important and imminent preventive function is its perception of erratic steering behaviors such as when the driver becomes drowsy, or falls in a short but dangerous lapse into sleep, and it emits visual and sound warning. The SDA CPU studies and memorizes the driver's normal steering habits in about ten minutes after his/her start-out (no one is likely to fall asleep during this CPU learning period). Input source is the photo-optical steering angle and velocity sensor built into the steering wheel, which is a component part of EPS, or electronic power steering offered in upper Bluebird models. Erratic steering behaviors that are typical of driver fatigue or drowsiness, as defined by Nissan, are more frequent steering maneuvers, and no steering correction for a prolonged period followed by a jerky motion, the latter being repeated in a drowsy state. The system regards such driver actions as braking, declutching, gearshifting, and putting turn indicators on as normal and conscious, and discounts any steering motions during these maneuvers from its judgement. It, too, considers steering behaviors on cornering as conscious efforts, however spirited they may be, and does not read steering signals for a pre-determined time period.



Nissan's popular mid-size car, the Bluebird, goes transverse engine and front wheel drive.



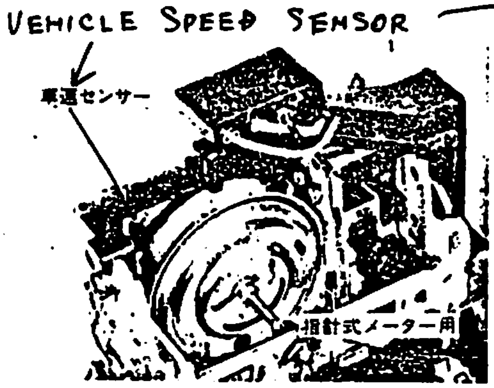
Bluebird power steering has adjustable power assist in three settings. Steering is electronically controlled, ensures progressive assistance.

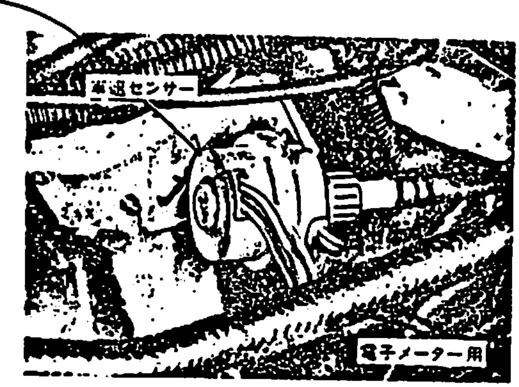
The basic SDA steering behavior warning function has been in development for more than ten years at Nissan's Central Laboratory. No price has been revealed as the system is offered in a deluxe package on certain top Bluebird models; however, a Nissan spokesman hinted a unit cost of no more than $85, inclusive of the incremental timing device feature.

The car, series U11 Bluebird, which looks outwardly quite similar to its conventional predecessor, has joined Nissan's fast expanding transverse engine, front wheel drive brigade. For the Japanese and most of export markets, the car is powered by lightweight, compact inline four cylinder engines in 1.6 through two-liter capacities, with outputs ranging from the base 1.6's 90 to a fuel injected turbocharged 1.8's 135 hp JIS. There is also a two-liter diesel version. All gasoline engines employ Nissan's twin-plug fastburn combustion system, in conjunction with catalytic converters to meet Japan's stringent emission standards. The US model, soon to replace the current inline six powered Maxima sedan, will be a stretched version powered by a new overhead camshaft V-6, again placed sideways.

For the new Bluebird, Nissan has developed a new inline automatic transaxle, incorporating a torque converter with top-gear lockup and four-speed planetary gearbox. Driveshafts are of equal length with provision of a central support bearing, to preclude torque steer on take-off. Suspension is all independent by MacPherson struts, the front pair located by pressed L-shape lower arms, and the rear ones by twin parallel transverse links and single trailing links. Variable shock absorbers are available on upper models, that will have three settings the driver can choose, Soft, Normal, and Firm. Likewise, optional EPS has three power assist modes in steering efforts that the driver may choose by a switch. Basic steering is by rack and pinion.

NISSAN SAFETY DRIVE ADVISOR
(pages V32-V38 and translations)





(3) スピーカー

右ドア　スピーカーを使用します。ラジオなどを聴いている最中に警報状況が発生すると、右ドア　スピーカーのボイス　インフォメーション　ユニットに接続されます。

8.　セーフティ　ドライブ　アドバイザー

車両走行時における健康な運転者のコンディションをステアリング操作状況や運転時間から推定して、休憩を促すシステムです。

8-1 機能概要

(1) 運転時間モニター

天候、運転時刻及び休憩時間の要素を加味した運転時間を積算し、その運転時間が2時間になると運転者に休憩を促します。

(2) 疲労運転モニター

転舵角速度センサーにより検出したステアリング操作と、疲労運転時にしばしば現われると考えられるステアリング操作の一定パターンが合致した場合、運転者に休憩を促します。

注：ステアリング操作は個人差、道路状況によって異なりますので、本システムは必ずしも疲労運転時に休憩を促すものではありません。

(3) Speaker

A speaker on right door is used.
If an emergency situation arises during a radio is on, a voice information unit on right door is turned on.

8. Safety Drive Advisor

While vehicle is in motion, this system presumes a condition of driver by steering performance and driving duration, and encourages driver to rest.

8-1

(1) Driving Duration Monitor

Weather condition and driving time are taken account of; when driving duration reaches to two hours, this monitor encourages driver to rest.

(2) Weary Driving monitor

A steering pattern is detected through steering rate sensor; when steering pattern detected matches to typical weary driving pattern, driver is encouraged to rest.

8-2

System Diagram

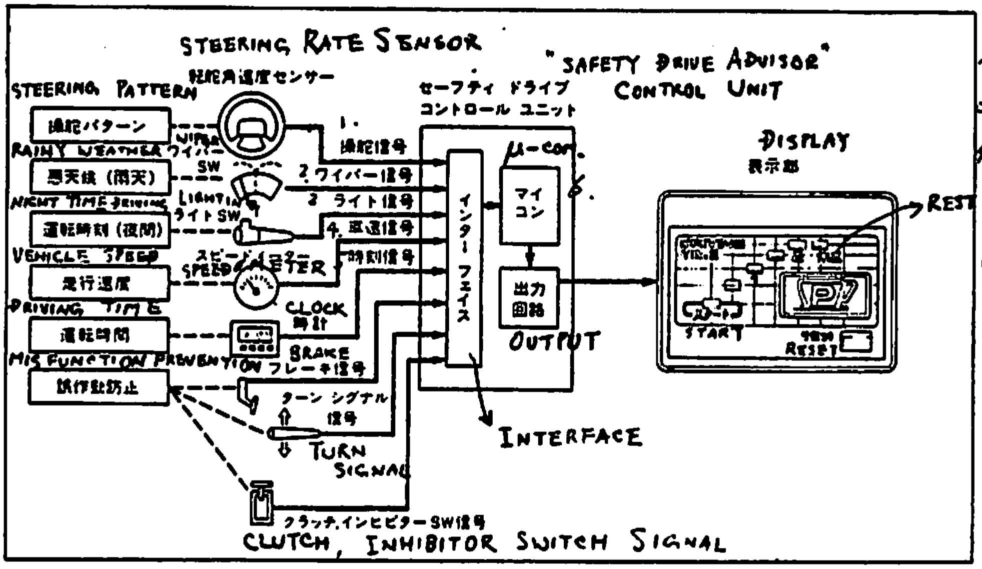
Safety Drive Control Unit processes each signal of steering rate sensor, wiper switch, light switch, vehicle speed, clock, brake switch, turn signal switch, and clutch switch(inhibitor switch). And it controls a display on display unit and buzzer.

(1) Display Unit

As a result of computation by Safety Drive Control Unit, picture display and buzzer encourage driver to rest. And driving duration is displayed on a driving duration indicator.
When a reset switch is pushed until buzzer is sounded, driving duration is reset and only a start indicator is lit.
Both picture display and buzzer are stopped by reset switch.

8-2 システム概要

SYSTEM DIAGRAM.



1. steering signal
2. wiper. signal
3. light signal
4. speed signal
5- time signal
6. micro-computer

本システムは、転舵角速度センサー、ワイパー　スイッチ、ライト　スイッチ、車速、時計、ブレーキ　スイッチ、ターン　シグナル　スイッチ、クラッチ　スイッチ（インヒビター　スイッチ）の各信号をセーフティ　ドライブ　コントロール　ユニットが処理し、表示部の表示及びブザーを制御するものです。

(1) 表　示　部

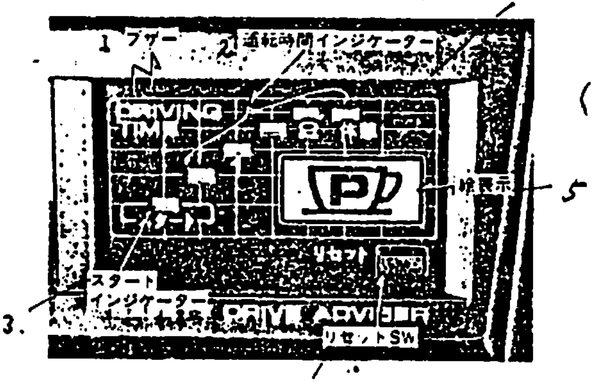
セーフティ　ドライブ　コントロール　ユニットの演算結果により、絵表示及びブザー音で運転者に休憩を促します。

また、運転時間を運転時間インジケーターに表示します。

リセット　スイッチをブザーが鳴るまで押すと運転時間はリセットされスタート　インジケーターのみ点灯します。

絵表示及びブザー音もリセット　スイッチにより停止されます。

DISPLAY UNIT.



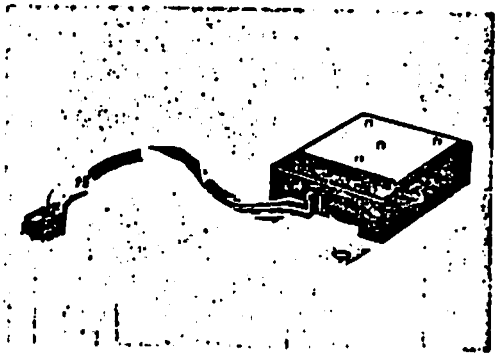
1. buzzer
2. Driving-duration indicator
3. Start-indicator.
4. re-set
5. picture-display
6. rest

(2) セーフティ ドライブ コントロール ユニット

CONTROL UNIT

各種センサー及びスイッチの信号により、運転時間の算出や操舵パターンの判断を行い、表示部に出力しています。

その他に、自己診断機能も有しています。



Detection

(3) 検出部

名称 Name	機能 Function	備考 Reference
転舵角速度センサー Steering rate sensor	操舵パターンの検出 detect steering pattern	Ⅲシャシー「9ステアリング」の項参照 Ⅲ Chasis "9 Steering" chapter
ワイパー スイッチ wiper switch	悪天候（雨天）時の走行を検出 detect a driving in rain	通常時の約1.2倍 multiplied by a factor of 1.2.
ライト スイッチ light switch	夜間の走行を検出 detect a driving at night.	
車速センサー vehicle speed sensor	車速の検出 detect a speed of vehicle	2パルス/回の信号 2-pulse signal
ドライブ フューエル モニター Driving Time Monitor	クロック信号の検出 detect a clock signal	
ブレーキ スイッチ brake switch ターン シグナル スイッチ クラッチ スイッチ (M/T) インヒビター スイッチ(A/T)	運転者が通常の運転操作を行っている状態を検出 detect a regular driving pattern of a driver	

urn signal switch ←

lutch switch ←

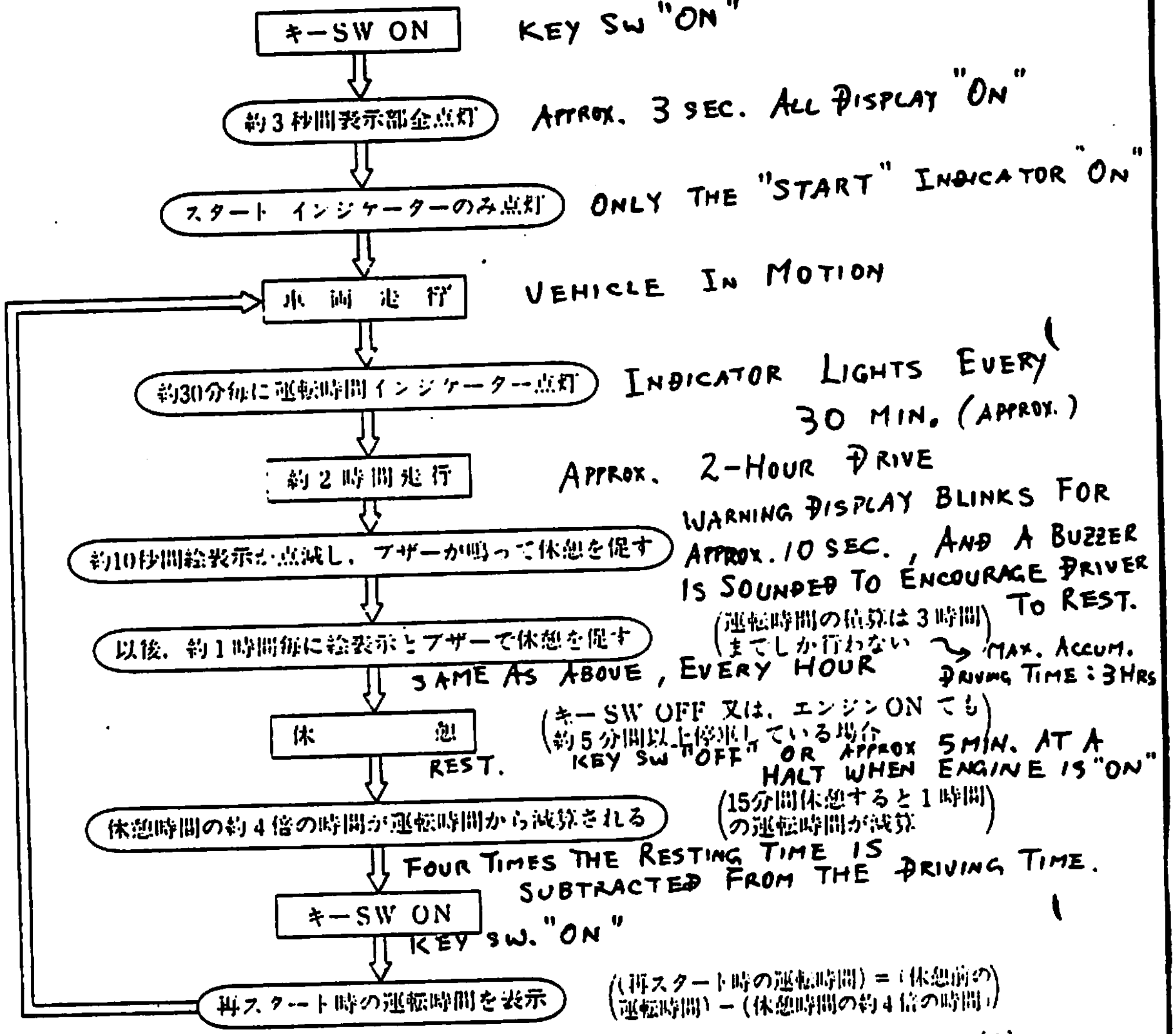
nhibitor switch ←

(2) Safety Drive Control Unit

This unit computes a driving duration and interprets a steering pattern by means of each sensor device and switch signal. It displays results on display unit. Beside the functions above, it has a self-diagonosis function.

8-3 システム作動説明 FUNCTION DIAGRAM

(1) 運転時間モニター (1) DRIVING TIME MONITOR



キーSW ON — KEY SW "ON"

約3秒間表示部全点灯 — APPROX. 3 SEC. ALL DISPLAY "ON"

スタート インジケーターのみ点灯 — ONLY THE "START" INDICATOR "ON"

車両走行 — VEHICLE IN MOTION

約30分毎に運転時間インジケーター点灯 — INDICATOR LIGHTS EVERY 30 MIN. (APPROX.)

約2時間走行 — APPROX. 2-HOUR DRIVE

約10秒間絵表示が点滅し、ブザーが鳴って休憩を促す — WARNING DISPLAY BLINKS FOR APPROX. 10 SEC., AND A BUZZER IS SOUNDED TO ENCOURAGE DRIVER TO REST.

以後、約1時間毎に絵表示とブザーで休憩を促す — SAME AS ABOVE, EVERY HOUR

（運転時間の積算は3時間までしか行わない） → MAX. ACCUM. DRIVING TIME: 3HRS

休憩 — REST.

（キーSW OFF 又は、エンジンON でも約5分間以上停車している場合） KEY SW "OFF" OR APPROX 5 MIN. AT A HALT WHEN ENGINE IS "ON"

休憩時間の約4倍の時間が運転時間から減算される — FOUR TIMES THE RESTING TIME IS SUBTRACTED FROM THE DRIVING TIME.

（15分間休憩すると1時間の運転時間が減算）

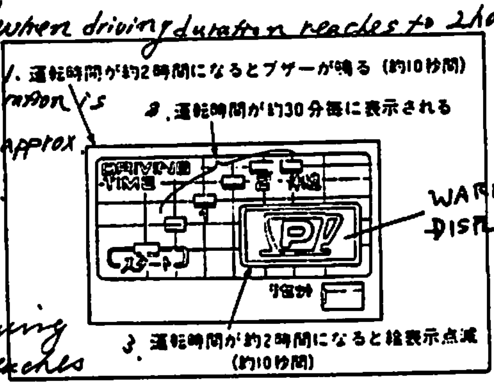
キーSW ON — KEY SW. "ON"

再スタート時の運転時間を表示

（（再スタート時の運転時間）＝（休憩前の運転時間）－（休憩時間の約4倍の時間））

1. when driving duration reaches to 2hours, a buzzer is sounded. (ten seconds)

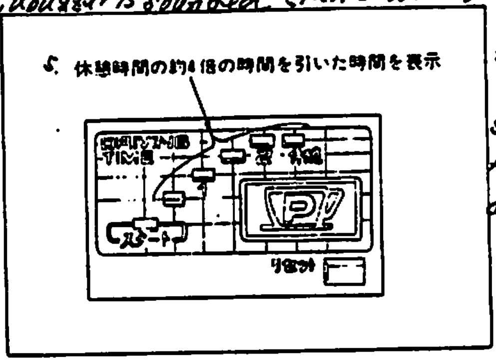
2' driving duration is displayed approx every 30 min



3' when driving duration reaches to 2hours, picture display blinks (approx. 10 seconds)

4' 運転時間積算時

4' adding



5' four times the resting time is substracted from the driving time, and displayed time.

6. 運転時間減算時

substracting.

Driving at night or in rain
夜間又は雨天時の走行

WHEN THE WIPER SWICTH OR THE LIGHTING SWITCH IS "ON", THE DRIVING TIME IS MULTIPIED BY A FACTOR OF 1.2. (THEREFORE, AN INDICATOR IS LIT EVERY 25 MIN.)

ライト SW 又は ワイパー SW ON

⇩

interpreted as driving at ← 夜間又は雨天時の走行と判断
ight or in rain.

⇩

実際の運転時間の約1.2倍を運転時間とし，運転時間インジケーターに表示

(約25分走行すると運転時間インジケーターが1つ増す)

⇩

hen driving duration eaches 2hrs, icture display and buzzrer encourage a rest.

運転時間か約2時間になると絵表示とブザーで休憩を促す

(ライト SW，ワイパー SWをOFFした場合その時点から通常運転時間計算になる)

upon turning off light - sw and wiper sw, a regular computation starts.

(2) 疲労運転モニター

(2) WEARY DRIVING MONITOR

車速が50 km h以上で走行 — VEHICLE SPEED ≥ 50 km/h.

⇩

ステアリング操作を検出 → STEERING PATTERN DETECTION

⇩

疲労運転時，しばしば現われると考えられる一定パターンのステアリング操作と合致したかどうか判断 → PATTERN MATCHING TO TYPICAL WEARY DRIVING PATTERN

- 通常走行時と比べ操舵頻度が増加する
- 通常みられないステアリング操作（ほとんどステアリングを動かさない状態と急にステアリングを動かす状態が連続するなど）をする

- Increase in steering frequency
- unusual steering pattern (no steering or abrupt steering)

⇩

運転時間に関係なく絵表示とブザーで休憩を促す

WARNING REGARDLESS OF DRIVING TIME

(3) システム誤作動防止機能

(3) SYSTEM MIS-FUNCTION PREVENTIVE MEASURES

ブレーキ ターン シグナル、クラッチ(M/T車)、A/Tコントロール レバー(A/T車)を操作した場合

WHEN THE FOLLOWING OPERATION IS SENSED.
BRAKE TURN SIGNAL CLUTCH A/T GEAR LEVER

ブレーキ，ターン シグナル，クラッチ，A T コントロール レバーを操作

⇩ ✪ CONTROL UNIT DISREGARDS STEERING RATE SENSOR FOR A PREDESSIGNED PERIOD

セーフティ ドライブ コントロール ユニットは転舵角速度センサーの検出信号を一定時間読み込まない

カーブ路を走行した場合 WHEN ENGAGING WINDING ROADS

カーブ路走行 — DRIVING ALONG A WINDY ROAD.

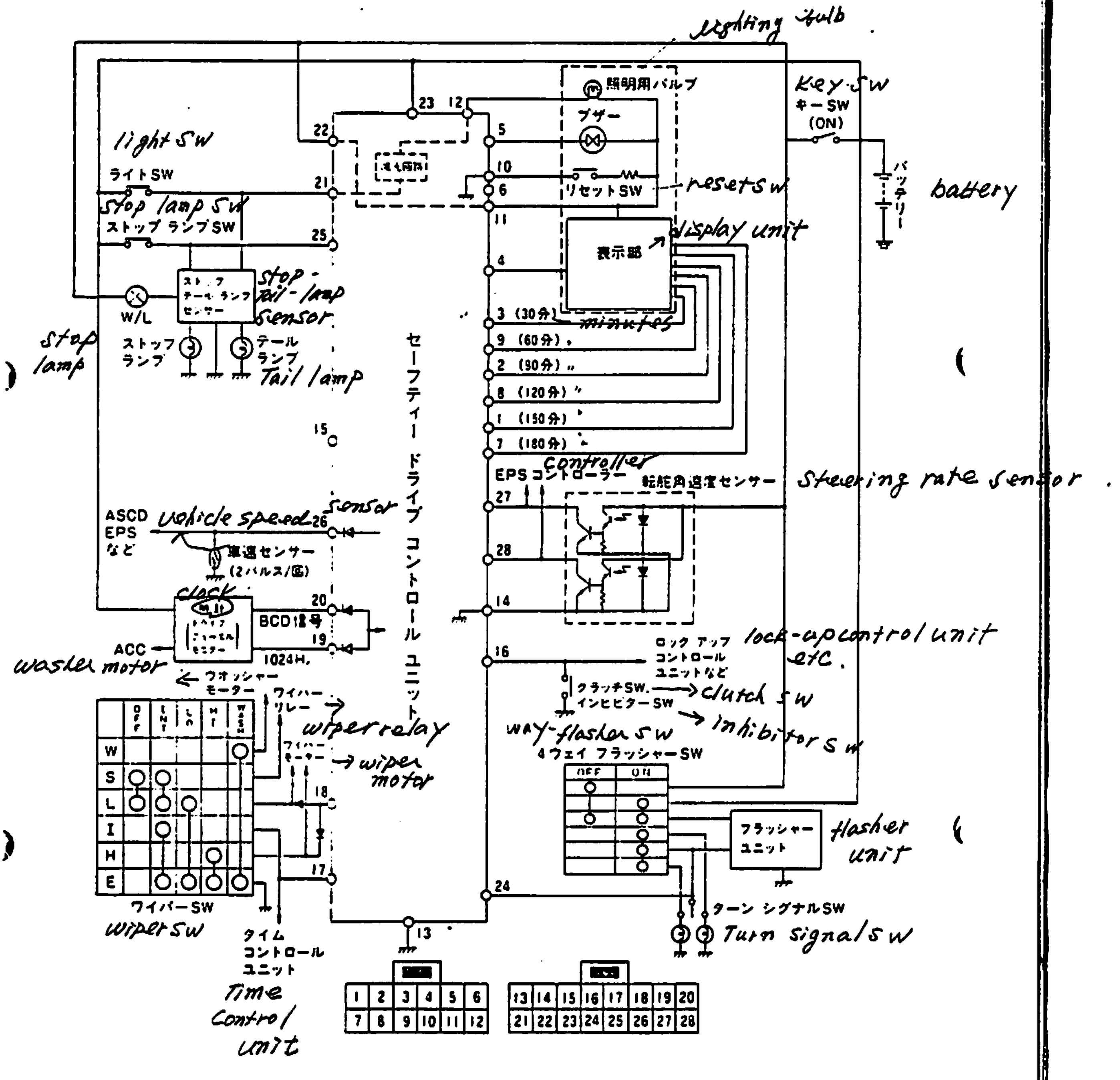
⇩ THE ROAD IS DETERMINED TO BE WINDY THROUGH STEERING SINGNAL

操舵信号によりカーブ路走行と判断

⇩ SAME AS ✪ (ABOVE)

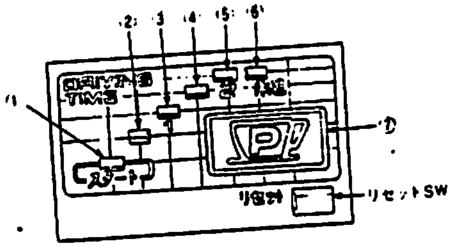
セーフティ ドライブ コントロール ユニットは転舵角速度センサーの検出信号を一定時間読み込まない

8-4 システム図 System Diagram



8-5 自己診断機能

自己診断機能には以下に示す項目があります。

項目	目的	操作	確認項目
出力チェック	セーフティ ドライブ コントロール ユニットが表示部に正常に出力していることを確認する。	キー スイッチをONにする。	約3秒間表示部が全点灯する。
入力チェック	各種スイッチ センサーの信号が正常にセーフティ ドライブ コントロール ユニットに入力していることを確認する。	出力チェック中（キー スイッチON後3秒以内）にリセットスイッチを押し、その後約30秒以内に各種スイッチ センサーを作動させる。	 信号が入った場合に点灯するインジケーター

インジケーター	入力信号
①	クロック
②	ワイパー スイッチ
③	車速センサー
④	ターン シグナル スイッチ
⑤	ブレーキ スイッチ
⑥	クラッチ スイッチ、インヒビター スイッチ
⑦	転舵角速度センサー

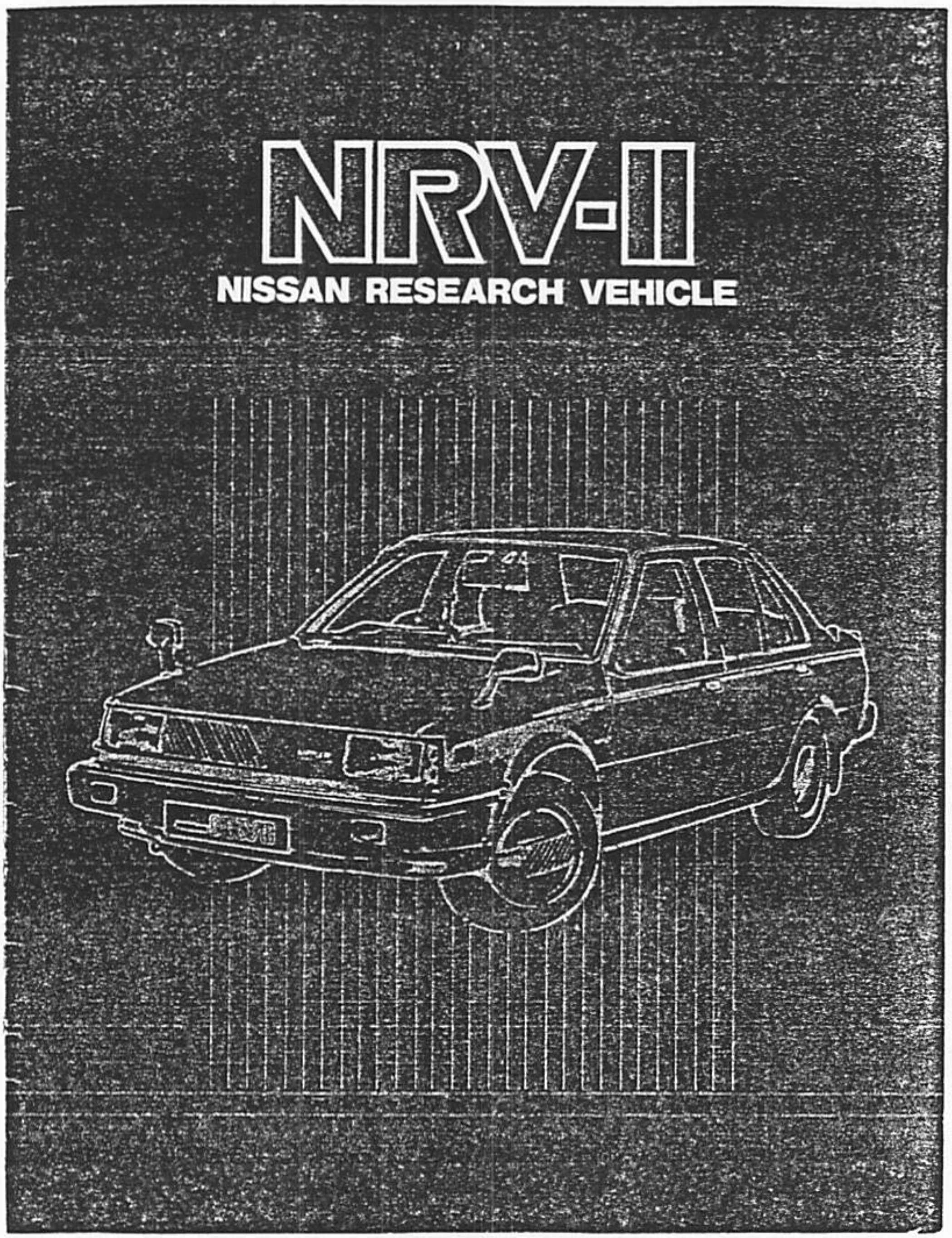
注：意入力チェック（約30秒間）が終了すると、通常の機能となります。

8-5 Self-Diagonosis Function

item	purpose	operation	confirmation
OUT PUT CHECK	To check Safety Drive Control Unit outputs to display unit normally.	Key switch ON	Display unit is all lit for approximately 3 seconds.
OUT PUT CHECK	To check each switch sensor signal input to Safety Drive Control Unit normally.	During output check(within 3 seconds after Keyswitch is On), reset switch is pushed, and after that (within 30 seconds) each switch sensor goes into operation	Indicator lit up when signal is received. Indicator Input signal 1 clock 2 wiper switch 3 vehicle speed sensor 4 turn signal switch 5 brake switch 6 clutch switch, inhibitor switch 7 steering rate sensor

CAUTION: After input check(approximately 30 seconds), normal functions return.

Appendix C (Con't)



NRV-II

NISSAN RESEARCH VEHICLE

Appendix C (Con't)

NRV-II···NOT SO MUCH AN EXPERIMENT AS A CAR FOR TOMORROW

The NRV-II Nissan Research Vehicle is a working example of Nissan's ideas for the car of the future. A future of diminishing energy resources and an ever increasing traffic population, with its attendant needs of greater active and passive safety. The NRV-II meets this future with advanced but practical technology, much of which is already well on the way to production reality. Advanced composite materials are used for weight reductions, and a turbocharged methanol fueled spark ignition engine has been adopted to extract the maximum power (and hence efficiency) from a given displacement, while also paving the way for the use of alternative fuels. Safety in the NRV-II means both passive safety in terms of maximized occupant protection, and active safety, which is achieved by equipping the car with a variety of systems designed to keep the car out of accident situations, and to make the driver's task as simple as possible.

To emphasize the practicality of the many ideas incorporated, the NRV-II is based on the Nissan Sunny, Nissan's top selling small family car. The Sunny was selected to give the research team the opportunity to demonstrate the possibilities for producing an ideal "car of the future" within limited external dimensions. The NRV-II measures a compact 4185 mm long by 1620 mm wide, the same as the Sunny. And in spite of the many safety devices incorporated and substantial side protection in the doors, the only interior sacrifice has been a mere 6 cm reduction in interior width. Further, thanks to the advanced lightweight materials used throughout the car, a fully equipped production version of the NRV-II would weigh only about 70 kg more than the equivalent Sunny.

The practicality of the NRV-II is further enhanced with a high performance 1.3 litre methanol fueled turbocharged engine that puts the NRV-II in a performance league with a superior two litre car. Maximum power output is 120 hhp at 6,000 rpm, which gives the NRV-II acceleration that takes it from 0 to 100 km/h in just 7.7 seconds.

With performance, convenience and safety, the NRV-II is much more than just an experiment. It is truly a car for tomorrow.

Appendix C (Con't)

FEATURES OF THE NRV-II

ENERGY CONSERVATION & WEIGHT REDUCTIONS

- Methanol Fueled Turbocharged Engine
- Plastic Fuel Tank
- Plastic Road Wheels
- Plastic Windscreen and Window

SAFETY

■ REDUCED DRIVER WORKLOAD

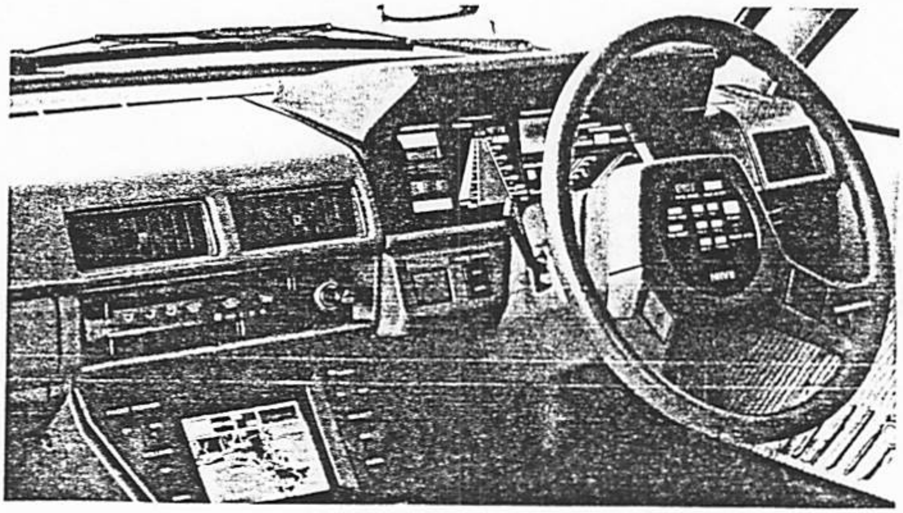
- Radar Auto-Cruise
- Multi-Colour LCD Instrument Display
- Fibre Optics/Steering Wheel Mounted Switches
- Voice Dialogue System
- Drive Information System
- Automatic Light Switching
- Automatic Windscreen Wipers
- Variable Tension Seat Belts

■ ACCIDENT AVOIDANCE

- Runflat Tyres
- Tyre Pressure Warning Device
- Drowsiness Monitor
- Four-Wheel Anti-Skid System

■ OCCUPANT PROTECTION

- Designing for Protection in Side Collisions



ENERGY CONSERVATION & WEIGHT REDUCTIONS

Methanol Fueled Turbocharged Engine

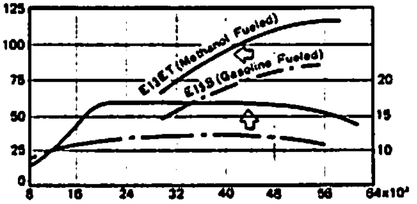
Powering the NRV-II is a small displacement (1270 cc) spark ignition engine with ECCS controlled fuel injection and a turbocharger, and adapted to run on methanol fuel. Methanol is one of the leading alternatives to gasoline as a fuel for automobiles, and may be derived from coal, of which large unmined reserves are known to exist. It is now relatively more costly to produce methanol than gasoline, but with oil supplies becoming increasingly scarce, the attractions of methanol are growing, and it may well be a major fuel as soon as the early 1980s.

Methanol also has the advantage over gasoline in a spark ignited engine that it diminates knocking, allowing a virtually free choice of compression ratio. In the NRV-II, a ratio of 11:1 has been combined with a turbocharger running with 400mm (Hg) of maximum boost for a high specific output power and optimum economy, while requiring only minor internal changes to the engine. For the future, advances in engine materials and design will allow higher compression ratios and hence even greater specific outputs.

A high compression ratio also means excellent drivability, eliminating one of the weak points of a low compression ratio gasoline fueled turbocharged engine. The turbocharger itself is conventional, raising both torque and horsepower across the engine speed range, and in particular the torque curve is flat from 1,600rpm to 5,600rpm.

The chief problem currently associated with methanol concerns low temperature starting performance, as methanol will not atomize below 60°. The engine of the NRV-II is equipped with an electric fuel pre-heater.

FULL LOAD PERFORMANCE OF METHANOL FUELED TURBOCHARGED ENGINE



Plastic Fuel Tank

A 40% weight reduction, worth 4.8 kg in the NRV-II, has been achieved by replacing the conventional steel fuel tank with one that is made of blow-molded plastic. In addition to saving weight, the plastic fuel tank is molded as an integrated whole, and so does not require a flange for joining the upper and lower halves, allowing the maximum use to be made of the available space. In the NRV-II, this has allowed an 8% increase in capacity. Further, the formability of plastic means that odd shapes can easily be produced, allowing every cubic inch of space to be exploited.

To eliminate the problems of fuel permeation, and fuel loss thereby, normally associated with plastic containers, the fuel tank of the NRV-II is formed of a special multi-laminar plastic lined with a barrier resin that is totally impervious to the fuel tank's contents.

Plastic Road Wheels

The NRV-II is fitted with experimental 13 inch fibre-reinforced plastic wheels. These bring savings of 12.5 kg per car compared with a set of four equivalent steel wheels, or 8 kg per car if the comparison is with aluminium alloy wheels. Reduced weight means better fuel economy, while the lower unsprung mass permits better wheel control for superior handling and greater ride comfort. In addition the use of plastic gives the designer virtual freedom with regard to wheel design, and even wheel colour.

Further wheel related weight savings have been achieved in the NRV-II by the use of run-flat tyres that allow the spare wheel to be dispensed with.

Plastic Windscreen and Window

A large proportion of the weight of a car's bodyshell is accounted for by the glass windows. In the NRV-II, a polycarbonite resin windscreen and windows have been used, to save 8.5kg—a 30% reduction. The resin surface has been treated with a hardener to ensure resistance to damage by windscreen wipers, etc.

SAFETY

REDUCED DRIVER WORKLOAD

Radar Auto-Cruise

Auto-cruise speed setting devices are gaining increasing popularity around the world as speed restrictions and the desire to drive economically increase the desirability of maintaining a steady cruising speed on the highway. With existing auto-cruise devices, however, there is no means for automatically responding to the presence of other vehicles.

The NRV-II is equipped with a 24 GHz radar that measures the distance to the vehicle in front, and displays the distance on a coloured graphic display on the NRV-II's instrument panel. In addition, a reference bar alongside the actual distance display indicates the calculated safe following distance, calculated in accordance with the NRV-II's speed and the prevailing weather conditions (a rain sensor is fitted to the windscreen in connection with the automatic windscreen wipers (see below)). In addition to displaying this information, if the NRV-II comes too close to the vehicle in front, a verbal warning alerts the driver and simultaneously interrupts the auto-cruise function to decelerate to the speed of the vehicle in front, in order to maintain a safe following distance. When the vehicle in front moves out the way, or accelerates out of range, the device automatically causes the NRV-II to resume the previously set cruising speed.

RADAR AUTO-CRUISE DEVICE

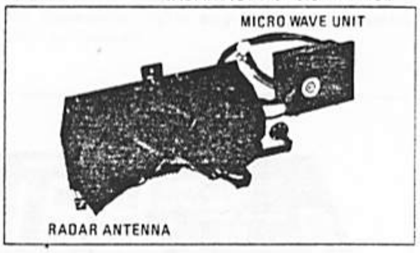
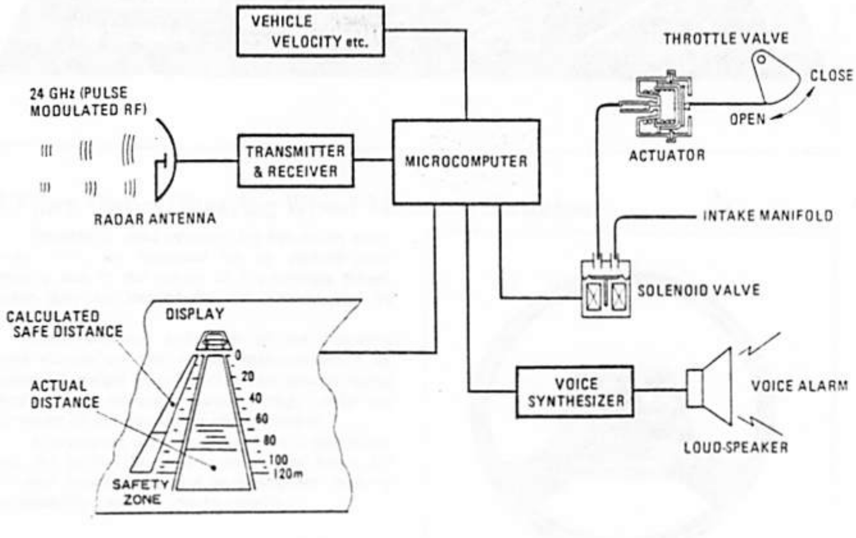


Fig. 1
RADAR AUTO-CRUISE DEVICE



SAFETY

● Voice Dialogue System

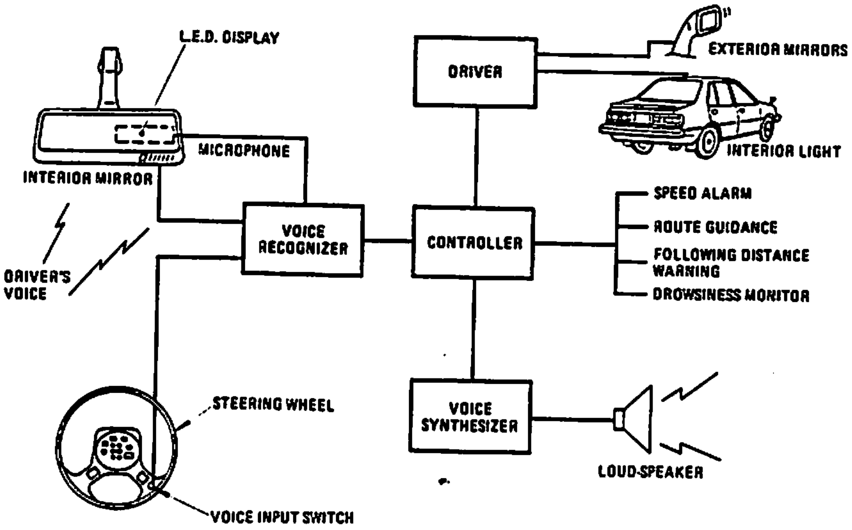
With the increasing volume of traffic on today's roads, the driver cannot afford to take his eyes off the road and his hands off the wheel. Thus to allow the driver to maintain his primary obligation, without missing important vehicle related information or having to do without control of certain vehicular functions, the NRV-II is equipped with a comprehensive voice dialogue system that allows the driver to interface verbally with his vehicle.

The driver simply presses a conveniently located "Voice Input Switch" on one spoke of the steering wheel, to switch on the microphone to accept any one of 26 verbal instructions. In return, the computer replies with an electronically synthesized voice which can issue instructions or warnings up to 50 seconds long.

Voice operated vehicle functions in the NRV-II include the input of route data for the drive information system, speed warning settings, and control of the exterior mirrors, interior light, and hazard flashers. The 26 commands may each comprise any repeatable sound, and so may be in any language, but a user must be registered with the system beforehand by running through the functions in sequence and recording his desired command for each specific function. Subsequent repetition of any of the commands by the registered user will be reliably identified by means of pattern matching with a filter bank, and the corresponding function will be automatically performed. For the registration process, the functions (and suggested commands) are spelled out on an LED display built into one corner of the interior mirror. Included in the commands are 8 possible directions of movement for the exterior mirrors and route guidance cursor, "stop", "clear", "faster", "slower", "advance", "return", 5 speed alarm settings, right or left exterior mirror selection, "interior light", "hazard flashers", "yes", "no", and "acknowledged".

The voice synthesizer that responds to the driver's commands also gives its own verbal warnings about driver drowsiness, insufficient distance from a vehicle in front, and route instructions (e.g. "Right turn ahead").

Fig. 2
VOICE DIALOGUE SYSTEM



NISSAN RESEARCH VEHICLE

SAFETY

● Drive Information System

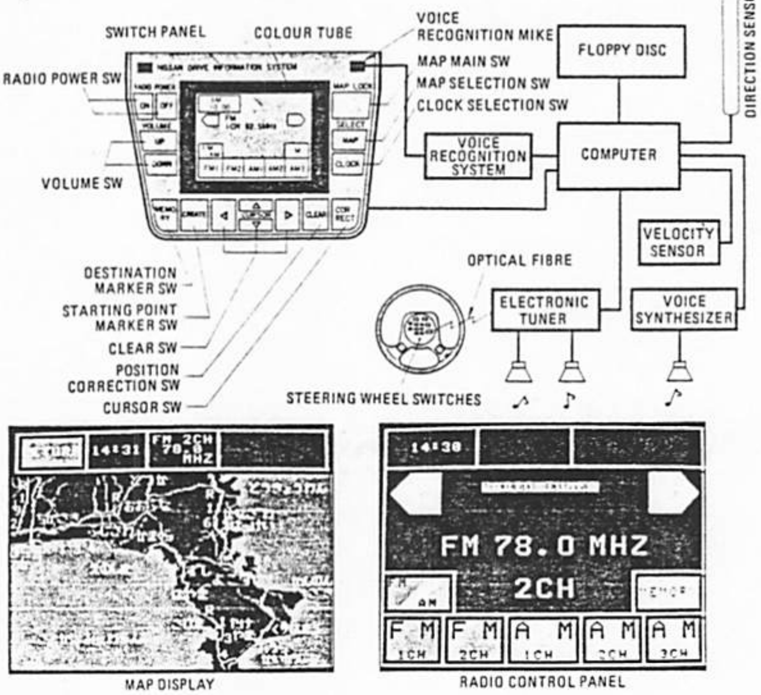
The NRV-II features a drive information system with a colour CRT to selectively display route maps, the time and date, malfunction warnings, and radio tuning information. In addition, the CRT is overlaid with a transparent switch matrix for a number of switching functions with a large touch target area. Switching is achieved by touching the relevant portion of the screen, as indicated by the display information, which may be changed to allow switch area to serve several alternative functions.

The principal feature of the drive information system is a route guidance system with a store of map information on a mini-floppy disc, which can be scanned and displayed in two scales on the screen. The driver designates his(her) present position by means of the cursor switches. A prospective route may be input verbally. Once on the move, the computer keeps the driver informed with verbal instructions (e.g. "right turn ahead") issued via the voice synthesizer.

The NRV-II's position in relation to the map, and a trace of the route actually travelled are indicated on screen. These are determined by a magnetic direction sensor and a distance recorder

Another function of the Drive Information System is to flash malfunction warnings on screen in the event of any problem. Such warnings automatically displace the existing screen information until the driver acknowledges the message. Once acknowledged, the display reverts to its previous function, and the warning is reproduced in miniature at the top right hand corner of the screen until remedial action is taken.

Fig. 3 DRIVE INFORMATION SYSTEM



MAP DISPLAY

RADIO CONTROL PANEL

SAFETY

Automatic Light Switching

The NRV-II is equipped with an automatic light switching system that automatically controls the car's head and tail lights in accordance with ambient lighting conditions. Ambient lighting is detected by means of photosensors mounted on top of the dashboard, and when the vehicle is running the lights are switched on or off accordingly. The headlights are also automatically switched off within 3 to 5 seconds each time the vehicle comes to a halt, to save energy and prevent dazzle while waiting at traffic lights, etc., and are switched on again as soon as the vehicle starts moving.

Manual switching of the lights is also possible.

Automatic Windscreen Wipers

The NRV-II is equipped with an automatic windscreen wiper system which optically detects raindrops on the windscreen and automatically starts or stops the wipers, and adjusts the wiping interval or speed in accordance with the amount of rain. Light is projected from inside the windscreen by light emitting diodes, and the presence or absence of rain on the windscreen is detected by light receptors which are sensitive to the light reflected from the front surface of the glass, and identify any sudden changes in the amount of light reflected such as are caused by the appearance of raindrops on the windscreen.

Variable Tension Seat Belts

To encourage their regular use, the seat belts in the NRV-II have been made as comfortable and easy to use as possible. The degree of slack in the belts is electronically controlled to be ideal, in accordance with vehicle speed, with the slack being gradually taken up as the speed increases.

ACCIDENT AVOIDANCE

Runflat Tyres

The NRV-II has been equipped with special runflat tyres of steel radial construction, which are designed to allow safe driving for up to two hours at speeds up to 80 km/h even after a puncture resulting in a complete loss of pressure. These tyres were developed jointly by Nissan Motor Company and Toyo Rubber Company, and were put on sale in January 1982 for vehicles used by handicapped persons and the police. Secondary tyre beads are used to keep the tyre from coming off the rim after going flat, allowing the use of a conventional type wheel rim, which has not been possible with other runflat tyre types.

Tyre Pressure Warning Device

A tyre pressure warning device is mounted inside the hub cap of each wheel, with a battery operated transmitter that sends a signal to a receiver inside the car to warn of a tyre pressure having fallen below a preset minimum safe level, due to leaks, etc.. This device, which sounds a buzzer inside the car, not only warns of punctures, but, since it monitors the actual tyre pressure, it can also aid reduced tyre wear and fuel consumption by warning of low tyre pressures.

Drowsiness Monitor

One of the NRV-II's most innovative features is a unique drowsiness monitor which detects decreased driver alertness and urges him to rest. In the development of this system, a physiological evaluation was made of brain wave patterns and associated physical behaviour, such as eye blinking. From this it was learned to assess the degree of drowsiness, and hence observe the associated patterns of physical manipulation of the vehicle's controls, such as the steering wheel. As installed in the NRV-II, the drowsiness monitor constantly monitors the driver's operation of the controls, and when any change of behaviour suggesting drowsiness is noted, the driver is alerted by means of a flashing light and a buzzer. If the driver continues to exhibit signs of increasing drowsiness, the warning light flashes and a voice warns "You are getting drowsy. Please rest."

SAFETY

Four-Wheel Anti-Skid System

One of the major safety developments of the eighties is the four-wheel anti-skid system that electronically controls the braking pressure to all four wheels to prevent skid-inducing lock-up. This contributes greatly to safety as it allows full braking to be used at any time—on curves, slippery surfaces, etc., without any loss of directional control.

In addition, since the anti-skid system prevents wheel lock-up on all surfaces, it satisfies the conditions for maintaining friction between the tyre and the road surface at the optimum level, ensuring the shortest possible braking distances, for an extra margin of safety.

OCCUPANT PROTECTION

Designing for Protection in Side Collisions

Designing automobiles to protect their occupants in the event of a collision is one of the most difficult, and at the same time one of the most important tasks facing today's automotive engineers. Considerable attention has been paid in the past to energy absorption in head-on and nose-to-tail collisions which constitute a high proportion of all serious accidents. However, it has begun to be realised that the occupant fatality rate is probably higher in accidents involving side collisions with penetration through the relatively narrow sides of the car. Further, while it is not too difficult to design the relatively long front and rear extremities of the bodywork to absorb collision energy, this task is not nearly so easy when dealing with the relatively thin sides.

The US government's National Highway Traffic Safety Administration (NHTSA) is conducting a study of protection during collisions from the side as a matter of priority in its long-range safety programme. Nissan, too, has attached considerable importance to this area of vehicular safety, and in the NRV-II, the target has been to combine a high level of safety with the practicality that is necessary to make the concept viable for production.

• PROTECTION STANDARD

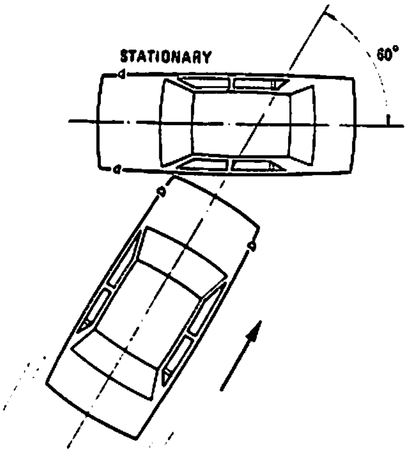
In designing a car for protection, one can only establish arbitrary standards based on repeatable experiments. This does not make the protection offered any less secure, but it does indicate the difficulty of ensuring absolute protection under all circumstances.

For the NRV-II the design brief was for occupant safety in a collision where a stationary vehicle is struck by a 2500 pound (1100 kg) vehicle travelling at 30 mph (48.6 km/h), at 60° to the stationary vehicle's longitudinal axis, as shown in figure 4.

• PROTECTIVE MEASURES

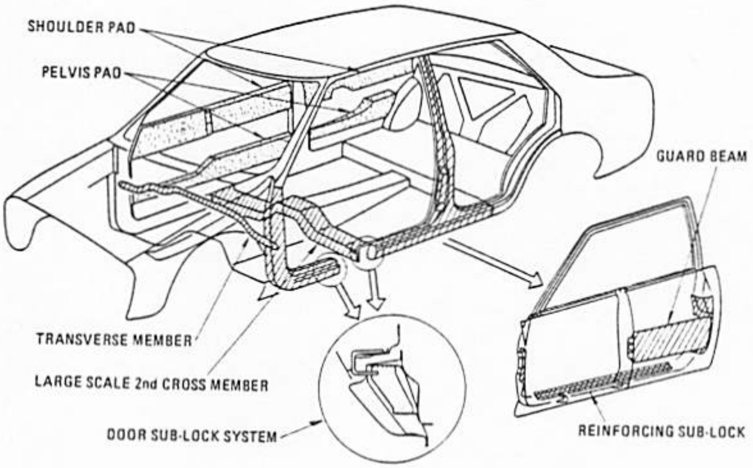
- Door reinforcement
- Reinforcing door sub-locks
- Sill and floor reinforcement
- A and B-pillar reinforcement
- Protective pads on the interior surfaces of the doors

Fig. 4
CONFIGURATION OF SIDE COLLISION TEST



SAFETY

Fig. 5
SIDE COLLISION PROTECTION



NRV-II – MAIN SPECIFICATIONS	
Length	4185 mm
Width	1620 mm
Height	1390 mm
Interior Length*	1835 mm
Interior Width*	1305 mm
Wheelbase	2400 mm
Suspension Front	Independent struts, coils
Rear	Independent trailing arms, coils
Tyres	Runflat Tyres 165/70SR 13

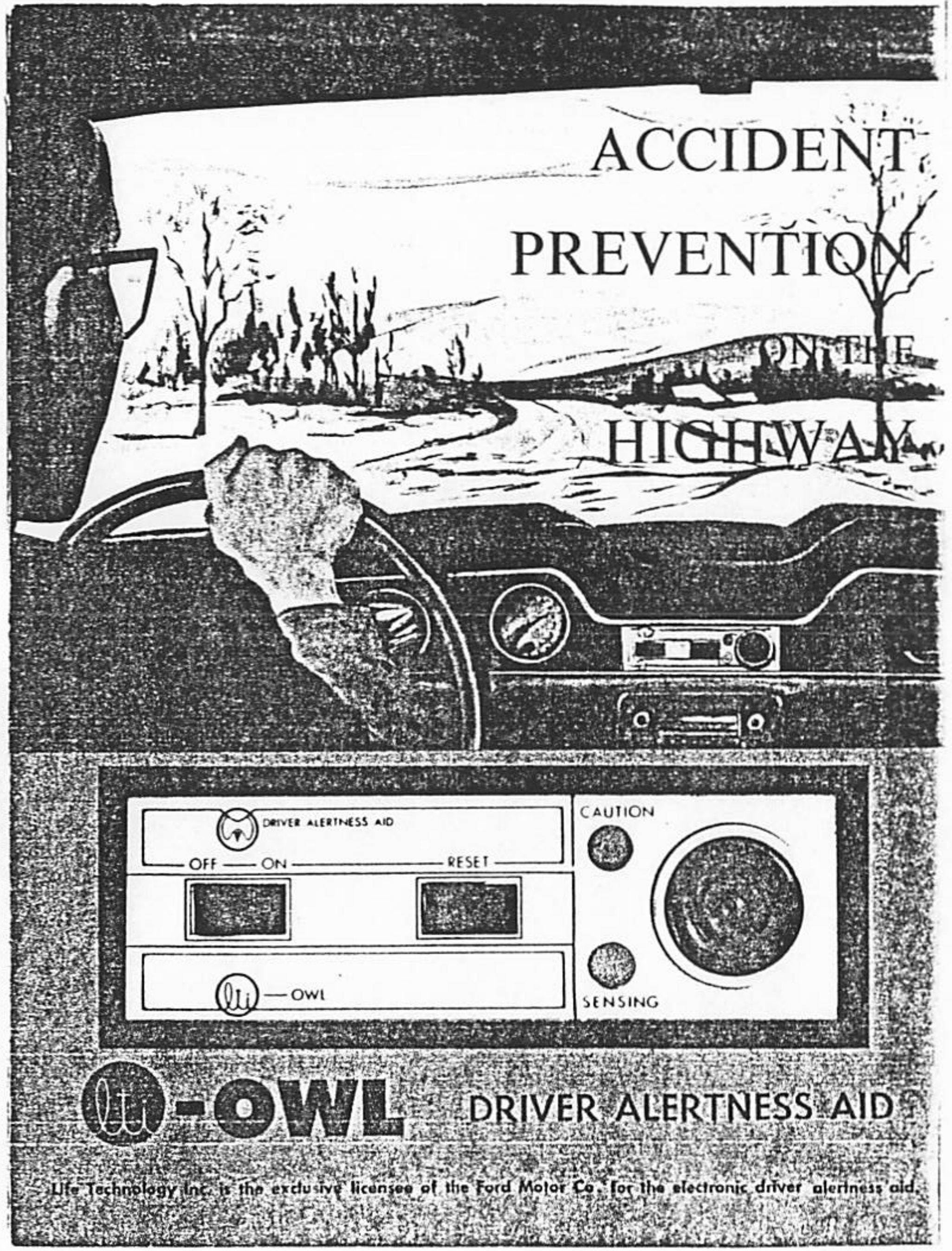
* Measured to JIS measurement standards.

METHANOL FUELED TURBOCHARGED ENGINE – SPECIFICATIONS	
Denomination	E13ET (ECCS)
Displacement	1270 cc
Bore × Stroke	76mm x 70mm
Compression Ratio	11.0:1
Turbocharger Max. Boost Pressure	400 mm (Hg)
Fuel	Methanol
Maximum Power	120 bhp/ 6,000 rpm (JIS)
Maximum Torque	17.0 kgm/ 3,600 rpm (JIS)

Acceleration 0 – 100 km/h. . . . . 7.7 seconds

Appendix C (Con't)

Life Technology Inc./Ford "Owl"



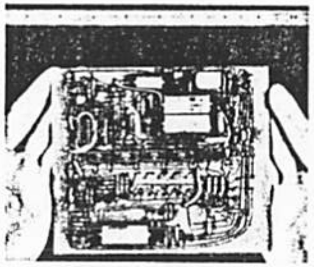
Life Technology Inc. is the exclusive licensee of the Ford Motor Co. for the electronic driver alertness aid.

Highway Accidents Don't
. . . "Just Happen"

Careful analysis over many years shows that driving error, not vehicle breakdown, is responsible for the overwhelming majority of highway accidents. This is true for all types of drivers. Even the most experienced and responsible can suddenly awake from a momentary lapse at the wheel to find himself in a hazardous situation. The cause? Usually fatigue, drowsiness, hypnosis, preoccupation or—in the other case—driving too fast.

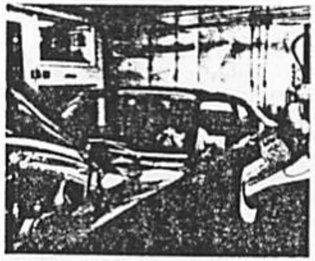
Yet most in-cab safety devices now in use or proposed—seat belts, padded dash, inflatable bags—assume accidents are inevitable, and are therefore designed solely for driver protection after impact.

OWL Gives Driver and Vehicle Protection Through Accident Prevention



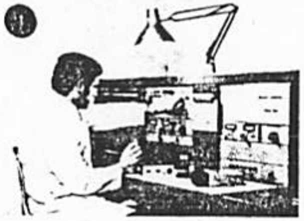
Now comes a completely new concept in highway safety — the **OWL** Driver Alertness Aid. The **OWL** is an electronic computer and warning device that alerts the driver when he has drifted too far from his normal driving pattern and before he becomes another accident statistic.

Devices similar to the **OWL** are standard in the flight decks of commercial airliners; why not in the cabs of highway vehicles as well? The main drawback has been cost and size. Until the advent of the small computer, size and cost would have been impossible obstacles, but solid state integrated circuits have made the **OWL** technically feasible and economically within the range of most drivers. Further, the dependability and shock resistance of these circuits makes the **OWL** as reliable as your car radio which means an absolute minimum of maintenance.



Ford researchers, who did the early work in this field, reasoned that if they could somehow "profile" a driver — that is, establish his normal driving pattern—they could use this information on long distance trips by continually comparing his road performance against it, warning the driver when deviations from the normal were leading him into dangerous highway situations.

After testing thousands of drivers they established the steering wheel reversal rate as the most accurate measure of a driver's "tracking" or profile. The research people at Ford developed this concept into an excellent experimental "Driver Attention Aid," but the device was manually adjusted and rather complicated for everyday use by all types of drivers.



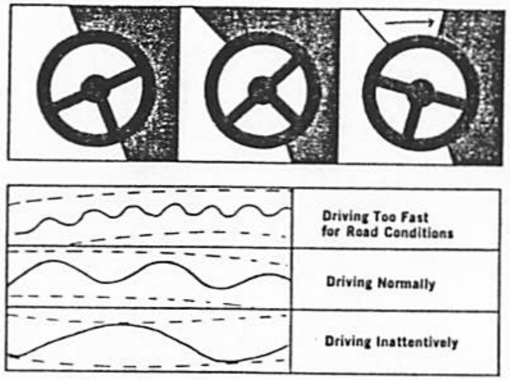
Life Technology Inc. is a California corporation that has been directing its efforts toward the development of instrumentation for preventive health systems. As a company they are interested in products dedicated to extending the life of the individual. Although they have been concentrating on medical instrumentation, they realize that their goal toward life preservation can also be met by developing equipment for preventing death on the highway. Therefore, Life Technology Inc. entered into an exclusive license agreement with the Ford Motor Company to further the development of the patented Ford research instrument and to make it commercially available.

Appendix C (Con't)

How the Iti OWL Works to Reduce Accidents

As you drive down the highway you are constantly moving the steering wheel back and forth to keep the car properly on the road. These movements are called steering wheel reversals, and a single reversal, which can be a back and forth motion as small as 2°, is illustrated at the right. Drivers can average anywhere from 20 to 50 such motions in one minute on the highway and each driver has his own individual profile or driver behavioral pattern.

The steering wheel reversal rate is the number of reversals a driver averages in a given period. This is a true profile of the individual driver's highway tracking habits. And this rate remains quite constant, even with noticeable changes in road conditions. For example, three different reversal rates are depicted at the right: high, medium and low. An alert driver in any of the reversal rate categories will unconsciously tend to drive at this same *rate* regardless of road conditions. He will usually slow down or speed up his vehicle to maintain a constant reversal rate which is comfortable for him. Occasionally, however, a driver becomes inattentive, causing him to reverse his steering wheel at a rate slower than his normal.



Conversely, there are times when driving too fast for conditions might raise his reversal rate above normal.

The Iti OWL uses this reversal rate principle, profiling the driver at the start of a trip and constantly comparing his ongoing tracking habits against this stored profile.

The Iti OWL in Operation

Driver starts vehicle, **OWL**, is on standby immediately—needs no warmup because of its solid state integrated circuits. It remains on standby until the vehicle speed reaches 35 mph. At that point the **Iti OWL** counts reversals for about three minutes, computes this into reversal rate and stores this tracking profile in the memory circuit.

The driver's ongoing reversal rate is then continually compared with his normal range stored in the memory circuit, and as long as the reversal rate falls within this range no warnings will be given.

If the reversal rate drifts outside the safety range warning devices will alert the driver so he can take the necessary action before serious trouble develops. There are two warning devices in the **Iti OWL**:

An audible alarm for too low a reversal rate, and
An amber caution light for too high a reversal rate.

Driver Inattentive — Alarm Sounds

If the reversal rate falls below the stored safety range, it is an indication that the driver is inattentive. This can be due to drowsiness, fatigue, medication (certain cold remedies, for example), hypnosis from long stretches of vacant highway or just plain daydreaming. Whatever the cause, when the reversal rate goes below the stored safety range an alarm will sound, waking the driver from his other world into the reality of the situation alert. Amazingly, the **Iti OWL** spots momentary driving lapses before the driver even realizes he is being inattentive and warns by the alarm well in time for the driver to return to normal, alert driving.

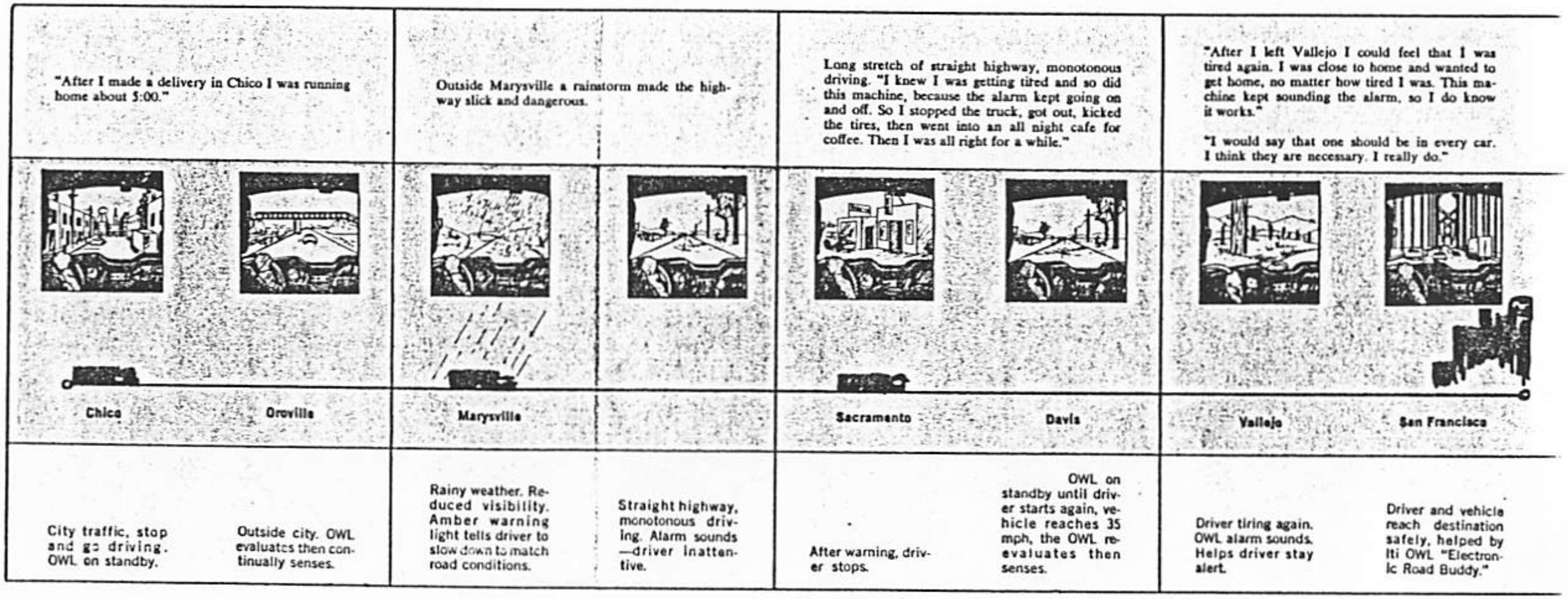
Driver Goes Too Fast for Road Condition — Amber Caution Light Appears

If the reversal rate goes above the stored safety range it is usually an indication that the driver is going too fast for existing road conditions or is in a general state of nervousness or tension. When this happens an amber caution light on the panel will signal the driver, and the light will go off only after the driver has corrected the cause of the high reversal rate.

Iti OWL Reports Only to the Driver

The **Iti OWL** is not a trip recorder. As a matter of fact it doesn't record at all. Instead, it is an electronic "Road Buddy" designed solely to help the driver be a better—and therefore a safer—driver.

This is Mr. L. E. "Jim" James, an owner-operator who drives contract for one of the largest moving and storage companies. We put an **Iti OWL** in his cab for testing under actual long haul conditions. Here's what Jim has to say about the **Iti OWL** "I found the machine very adequate. The thing that I noticed most while driving is that the machine will definitely tell you when you are not paying attention. After the warning comes on, if you check back on your driving pattern, you will definitely find that you have not been paying attention."



"After I made a delivery in Chico I was running home about 5:00."

City traffic, stop and go driving. OWL on standby.

Outside city. OWL evaluates then continually senses.

Outside Marysville a rainstorm made the highway slick and dangerous.

Rainy weather. Reduced visibility. Amber warning light tells driver to slow down to match road conditions.

Straight highway, monotonous driving. Alarm sounds —driver inattentive.

Long stretch of straight highway, monotonous driving. "I knew I was getting tired and so did this machine, because the alarm kept going on and off. So I stopped the truck, got out, kicked the tires, then went into an all night cafe for coffee. Then I was all right for a while."

After warning, driver stops.

OWL on standby until driver starts again, vehicle reaches 35 mph, the OWL reevaluates then senses.

"After I left Vallejo I could feel that I was tired again. I was close to home and wanted to get home, no matter how tired I was. This machine kept sounding the alarm, so I do know it works."

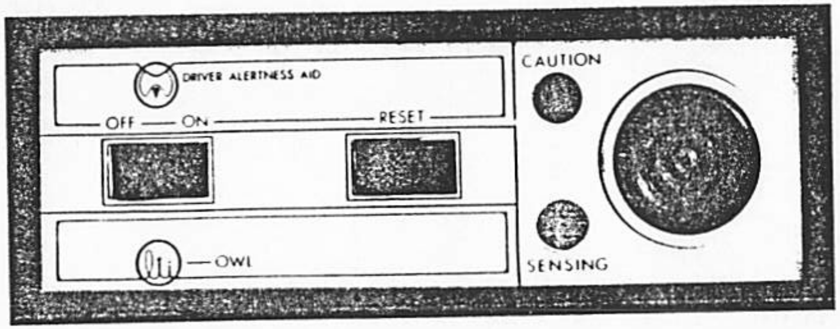
"I would say that one should be in every car. I think they are necessary. I really do."

Driver tiring again. OWL alarm sounds. Helps driver stay alert.

Driver and vehicle reach destination safely, helped by Iti OWL "Electronic Road Buddy."

Highway accidents can be drastically reduced. Life and property can be dramatically saved with the lti OWL Driver Alertness Aid. An electronic sensing device that follows steering wheel reversals can alert the driver to physiological changes such as drowsiness, fatigue, hypnosis, preoccupation or tension.

A small computer incorporated in the sensor can automatically calibrate to the characteristic driving habits of any operator and warn him when he has drifted too far from his driving norm to constitute a hazard to himself and others on the road.



lti – OWL DRIVER ALERTNESS AID

lti-OWL DRIVER ALERTNESS AID

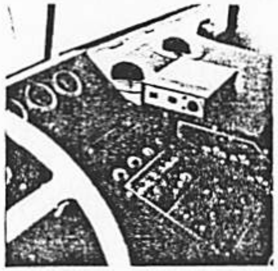
Driver Need Not Touch the lti OWL

Under normal conditions the driver doesn't touch the lti OWL. It doesn't require any calibration and there aren't any knobs to set or dials to read. You don't even have to turn it on and off; it's wired in series with the ignition. In short, it's completely automatic.

On rare occasions the lti OWL may give out warnings when the driver is neither tense nor inattentive. This is usually caused by the driver being "profiled" under abnormal conditions such as a stretch of highway under construction or the driver being unusually tense at the start of a trip with the tenseness relaxing as he drives. All the driver has to do in such cases is touch a reset button. The lti OWL will then profile and store a new pattern and continue to work for the driver. At no time does the lti OWL take over the driving — the driver is always in the driver's seat.

INSTALLATIONS

In-Dash
Circular Model



Rectangular Model
Above Dash

TECHNICAL SPECIFICATIONS

Temperature Tolerance
The lti OWL has been tested from −20° to +140° F.

Vibration Tolerance
The lti OWL has been tested over 10 times the force of gravity.

Electrical Requirements
12 volts D.C.
Draws less than one amp.

Dimensions
Under Dash Rectangular Model
Width—6½ inches
Height—2½ inches
Depth—8½ inches

In-Dash Circular Model
2-1/16 inches diameter by 2¾ inches deep.
(fits in standard cutout for small gauge)

life technology inc.
2361 stanwell drive concord, california 94520 telephone (415) 687-4760

Appendix C (Con't)

Safex "Drive Alert"

DRIVE ALERT

A NEW DEVICE THAT CAN SAVE YOUR LIFE!

GUARD AGAINST FALLING ASLEEP AT THE WHEEL

Patent # 4354179

ONLY $\$29^{95}$ Including Battery

TRULY UNIQUE WARNING DEVICE THAT EVERY DRIVER SHOULD OWN!

- 18 pre-selected positions
- wear on either ear, fits over glasses
- light weight, less than 1 oz.
- travel case attaches to dash or any surface.
- 86 Decibel 2000 Hertz Frequency.
- Recommended For All Drivers.

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YES! Please rush me my DRIVE ALERT(S) on a full money back guarantee.

☐ One Drive Alert for only $29.95 Plus $2.00 Shiping AND Handling

☐ SAVE! More! 2 for just $49.95 Plus $2.50 Shipping AND Handling

Enclosed is ______

Charge It! ☐ MC ☐ VISA

Acct. No. ______

Exp. Date ______

NAME ______

DATE ______

CITY ______ STATE ______ ZIP ______