NATIONAL RESEARCH COUNCIL

TRANSPORTATION RESEARCH BOARD

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June 18, 1999

Dr. Christine M. Johnson
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Federal Highway Administration
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Room 3401
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Dear Dr. Johnson:

At the request of the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) of the U.S. Department of Transportation (DOT), the Transportation Research Board (TRB) of the National Research Council has convened the Committee for the Review of the Intelligent Vehicle Initiative (IVI). The committee held its first meeting in Washington, D.C., on April 15-16, 1999. The enclosed committee roster indicates the members in attendance.

This letter report is the first of three annual written reviews of the IVI program. Within the broad mission of DOT to "improve the quality of [the] nation's roads and the vehicles [that] operate on them" (JPO 1997, 4; JPO 1999, 2), the primary stated goal of IVI is to enhance highway safety by accelerating the deployment of driver-assistance technologies, such as collision avoidance systems and operator and vehicle diagnostic systems, in passenger, commercial, transit, and special-purpose vehicles. Secondary goals are to improve highway efficiency, mobility, productivity, and environmental quality. The program is managed by the JPO, representing the appropriate modal administrations of DOT. The JPO will work in partnership with manufacturers, suppliers, state and local governments, and other stakeholders to accomplish the program goals.

The committee's charge for this first review is to comment broadly on the IVI program goals, program design and operation, strategic plan, and individual program elements. As the program matures, future reviews will be focused to a greater extent on an assessment of individual partnerships, program operations, and progress on achieving program goals. In addition, the JPO provided the committee with the following four questions for consideration over the life of the TRB peer review activity:

1. For the amount of money DOT can invest in this research effort, is the government doing the right things? Is DOT investing its money and human efforts wisely?
2. Is the planned human factors research enough? Is it appropriate?
3. What proportion of effort should be invested in nonpassenger (i.e., truck, bus, and specialty) vehicle platforms?
4. Is DOT's relationship with the industry appropriate?

The committee began its review by hearing a series of presentations from DOT IVI program staff in an open session. The staff presented an overview of the program goals and objectives, rationale for federal involvement, and budget; provided a brief history of the program; discussed the program strategy and proposed management structure; and introduced a roadmap of program technical activities. Brief presentations then followed on each of the technical platforms— light (i.e., passenger) vehicles, commercial vehicles, transit vehicles, and specialty vehicles— and on cross-cutting issues. The committee appreciated the openness of the DOT staff and their candor in the ensuing discussions. Next, the committee heard from representatives of the safety and user communities concerning their experience with IV technologies and their views on the program. Finally, the committee met in executive session to deliberate on the information presented and to develop this report.

In responding to its charge, the committee devoted the majority of its attention to the IVI program goals and objectives, and to the federal role (question 4). This focus resulted from the committee's recognition that, for the program to be a success, its mission and specific goals, along with their timing and rationale for accomplishment, must be clear, and the roles of government and industry must be appropriate and well defined. Based on the information received at this first meeting, the committee identified these as the most critical areas in which immediate improvement is needed. Hence this letter report concentrates primarily on these topics, although other major issues within the committee's charge are also addressed.

In view of the brevity of this first meeting and the broad range of topics covered, the committee found it challenging to absorb, understand, and comment knowledgeably on the wealth of information provided on a program of this complexity. The committee reached consensus on many of the key points in this report (see the bolded statements in the following sections), but hastens to add that they should be interpreted as first impressions.

WHAT ARE APPROPRIATE IVI PROGRAM GOALS AND OBJECTIVES?

IVI program materials— the Business Plan (JPO 1997) and the Program Overview/Discussion Document (JPO 1999) provided to the committee— link specific program goals to the broader mission of DOT in a way that several individuals found confusing. The main point of confusion was the scope of program activities, specifically whether highway as well as vehicle improvements are part of the IVI program mission. In their presentations to the committee, IVI program staff made clear the safety goal and vehicle-related, near-term focus of the program, but the committee believes the documentation would be more compelling if program goals were described more simply and clearly in future revisions of these materials.

The committee then turned its attention to the primary stated goal of the IVI program— enhanced safety, that is, a reduction in highway crashes and resulting injuries and fatalities. When the IVI Business Plan was first published (JPO 1997), the program was expected to be funded at approximately $50 million annually, and secondary goals of improved highway efficiency, mobility, productivity, and environmental quality were also prominently featured. Today, given a scaled-back IVI annual budget of approximately $25 million, the latter goals appear to be appropriately downplayed.

During their presentations to the committee, DOT program managers provided compelling evidence of the types of crashes— and the role of human error in those crashes— that might be addressed through a program designed to encourage the equipping of motor vehicles with technologies that can make the driving task safer. **The committee is unanimous in its support of safety as the primary program goal. Moreover, it agrees that DOT has an appropriate and important role to play in facilitating the development of IV technologies, and evaluating their impact on safety as they appear on more and more vehicles.**

The committee's chief concern is how DOT's involvement will serve to advance the program goals. DOT views as a critical federal role acceleration of the commercial availability of IV technologies (JPO 1997, 8; JPO 1999, 2), and has proposed a logical sequence of joint public- private activities based on the assumption that research on and operational tests of those technologies will precede their deployment in the marketplace. Technology acceleration can be an appropriate government role when regulation or the threat of regulation requires or provides a strong incentive for industry action, and substantial federal resources are brought to bear. These conditions are evident, for example, in the Partnership for a New Generation of Vehicles (PNGV) program, a public- private partnership that has succeeded in accelerating the development of technologies and materials designed to achieve significant increases in passenger vehicle fuel economy[1].

The committee questions, however, the extent to which DOT can affect the pace of commercialization of IV technologies in view of its nonregulatory approach and small program budget.

In addition, the IVI program is emerging in the context of a technological revolution in the automotive sector as vehicles are rapidly being outfitted with the products of information, communications, and electronics technologies. Industry, which is taking the lead in the introduction of these technologies, has already deployed some of the IV technologies that appeared in the 1997 IVI Business Plan, such as driver navigation systems and night vision systems, without government intervention or evaluation, apparently leapfrogging the sequence of events assumed by the program. For example, Cadillac is introducing a night vision enhancement system on its new models despite the fact that DOT-funded research is under way on the pros and cons of various prototype night vision systems (JPO 1999, 19). As one of the automobile manufacturers stated, "The motor vehicle industry is heavily influenced by the consumer market, and there is little that the IVI can do to actually deploy the systems . . ." (Toyota Motor Corporation 1998, 2).

At the same time, however, many of the technologies will have direct effects on the driving task and can be expected to affect driver behavior in unpredictable ways. An important role for DOT not currently stated in the IVI program materials is to understand the safety effects of technology that has already entered the marketplace, as well as that currently in development. **The committee believes the safety goal of the IVI program would be better served if DOT were to acknowledge the limits of its role in accelerating the deployment of in-vehicle technologies, and place greater emphasis on accelerating enabling research[2], facilitating standards setting, and understanding the crash reduction potential and other safety effects of candidate IV technologies both in development and commercially available.**

The current focus on accelerating the adoption of IV technologies also has important implications for the range of human factors research that will be undertaken under the program[3]. DOT has recognized the importance of human factors research to the success of the program and the critical role of government in initiating that research. However, the current federal focus on technology acceleration has diverted attention from one of the most critical areas of human factors analysis— the effects of technology on driver behavior in the real world and the implications for the safety of the driving environment. Currently, human factors research in the IVI program appears to be focused on technology testing under laboratory or highly controlled conditions that approximate those of the real world (e.g., simulator studies, test track operational tests). In this connection, the committee discussed the disappointing experience with antilock braking systems, an IV technology already on automobiles. Highly controlled testing of this technology before it became commercially available had led to expectations of large safety benefits that, according to several studies, have not been realized[4]. This unexpected outcome may have arisen from several causes, such as unanticipated changes in driver behavior (e.g., faster driving because of enhanced brake performance), failure to foresee the full range of driver responses to the systems (e.g., driver confusion due to unexpected brake noise and pedal vibration when the antilock brakes are engaged), and poor understanding of how to operate antilock braking systems on the part of new car buyers. With this example in mind, **consideration should be given to allocating part of the program budget to human factors research on IV technologies that have already reached the marketplace.**

The program would also benefit from a more detailed discussion of how proposed human factors research will be integrated into each stage of technology development and assessment. Research on human factors is needed early in the technology development process to ensure the appropriate design of new technologies. For example, the design of effective driver warning systems first requires research on what information drivers need, as well as their ability to process and react appropriately to that information. Human factors research of this type should help identify issues that need to be resolved and flag problems that could prove troublesome once warning systems become commercially available. The committee discerned little from DOT staff or IVI program materials about the nature of this research, how it would be conducted (e.g., possible use of the National Advanced Driving Simulator), what experiences from other sectors (e.g., aviation, defense) or countries (e.g., Japan, Europe) could be brought to bear, or who would be involved (e.g., academics, human factors experts in the national laboratories).

The effectiveness of IV technologies may be enhanced if human factors experts are encouraged to work cooperatively with engineers at each stage of conception, design, development, testing, and evaluation. Critical human factors research issues include how the IV technologies relate to one another and to equipment already on the vehicle from the perspective of the driver’s ability to handle the new capabilities. Such systems engineering and systems integration issues are appropriate for IVI program support. Finally, once the technologies become commercially available, human factors research is needed to examine driver response and adaptation to the technologies, as well as unintended consequences from a safety perspective.

A proactive federal role in each of these areas is needed.

WHAT IS AN APPROPRIATE FEDERAL ROLE?

At the broadest level, the committee believes the federal government's role in the IVI program should be to facilitate (rather than accelerate) the development and to monitor and evaluate the deployment of new motor vehicle technologies with the potential to make the driving task safer. This role implies government involvement before, during, and after IV technology deployment, recognizing that government cannot control the introduction of these technologies in the marketplace (unless, of course, it opts to require them by regulation).

In the committee's judgment, the appropriate role for government in the IVI program should be more sharply defined than it is at present, so that the value added by government participation will be evident. Scaled-back IVI program resources make it even more critical for the role of government to be clearly defined and well focused relative to the roles of industry, suppliers, universities, and other IVI stakeholders. In general, the government role in the IVI program should encompass activities, such as those discussed below, that industry or others are unlikely or unwilling to perform. Several of these activities are noted in IVI program materials, but they are scattered throughout the documentation.

Research

Enabling research. Such research could involve the development of performance specifications; the design of metrics and approaches for measuring benefits gained from technology deployment (e.g., crash reduction); and consideration of ways to reduce the liability risks of technology introduction, often perceived as a critical barrier to more rapid technology deployment. Precompetitive, typically longer-term, research of this type is an appropriate area for federal involvement. An additional government role could be to enlist the participation of researchers who have not traditionally partnered with the automotive industry in technology development. This topic is discussed in greater detail in the following section.

Research on technology integration. An appropriate role for government is to investigate motorists' reaction to the addition of new driver information and control technologies; such research can be conducted either as the technologies are being developed or after they have been deployed in vehicles. Government should support industry investigation of such critical interoperability issues as the need to integrate new IV technologies with existing systems so the driver is not overwhelmed with information or conflicting signals. Moreover, industry is unlikely to examine the effects of after-market add-ons or retrofits. Nor will industry necessarily focus on the need to design technologies that will operate in sufficiently similar ways on different vehicle models so as not to confuse the driver.

Research on unintended safety consequences of commercially available IV technologies, particularly those with potential negative safety effects. Once technologies have been deployed in vehicles, industry does not have a strong record of evaluating their effects on the driver from a safety perspective. For example, one hypothesis for the disappointing findings on the safety benefits of antilock brakes is that some drivers tend to adapt their behavior (i.e., drive faster, closer), using up some of their new safety margin by adopting riskier driving behaviors. A recent simulator study of early models of adaptive cruise control technology raised similar issues concerning undesirable behavioral adaptations to the presence of the technology (e.g., higher speeds, more driving in the left lane, and more weaving behavior) (Hoedemaeker and Brookhuis 1998). Research on the prevalence of and reasons for unwanted or unexpected driver adaptations that reduce the potential safety gains from new technologies is a legitimate and important area for federally sponsored research.

Data

Government should help provide at least three types of data:

- *Data and methodologies for benefit estimation* to help define, even in a qualitative way, the expected safety benefits of different technologies and the likely magnitude of their effects on the total highway safety problem. These data should assist industry in making the benefit-cost assessments needed to justify technology investments. The data may also help identify those technologies with the greatest expected safety payoff, and consequently assist IVI program managers in setting their own priorities. The committee believes the data it was provided on the expected safety benefits of IV technologies were too vague and unfocused to provide a basis for technology assessment.
- *Baseline data on driver behavior* for use in monitoring and studying changes in driving patterns introduced by new technologies and adaptive behaviors that may affect safety outcomes.
- *Data on crashes*— particularly on their incidence and, to the extent possible, their causes— that could be reduced or

avoided altogether with the deployment of IV technologies.

Performance Specifications and Standards Setting

Government has an appropriate role in helping to develop testing and evaluation protocols, as well as participating in the financing of operational tests of IV technologies. Government also can help develop and validate performance specifications and design guidelines for the technologies. Finally, it can facilitate the standards-setting process once technologies have been developed. Standards setting will be most effective if it involves collaboration and cooperation among vehicle manufacturers, government, and other relevant parties (e.g., standards-setting organizations).

Infrastructure Provision

A key government role is to facilitate the necessary infrastructure investments for specific IV technologies that require cooperation between the vehicle and the highway (e.g., intersection collision avoidance systems). Ensuring timely provision of the requisite infrastructure requires not only federal but also state and local government involvement.

The committee recognizes that several of the above government roles are defined at various points in the IVI program material provided by DOT. **The committee urges that this information be brought together in one place and clarified so that the federal role, and the resources that support it, is clearly identified for each program activity.**

WHAT OTHER ISSUES MERIT DISCUSSION?

As noted earlier, the committee focused the majority of its attention on the questions of program goals and the federal role in achieving those goals. However, the committee also touched on several other topics encompassed by its charge, which are elaborated below. It should be noted that the committee's comments on many of these topics are preliminary; consensus was not always evident, and in some cases the topics simply raised further questions.

Program Resource Levels

Without understanding more of the program details, particularly the dimensions of the research program and the types of partnerships that will emerge, the committee is unable to comment at this point on the adequacy of funding both for the program as a whole and for its individual components. However, as previously discussed, the committee was made aware that the IVI program has been scaled back from a more ambitious long-term program to promote intelligent transportation system technologies for mobility and efficiency as well as safety. According to DOT staff, the narrower focus resulted from these cutbacks in the larger program budget, and from a decision to focus on technologies with potentially large safety benefits that could be brought to market in the nearer term. **Given the reduced budget, narrower mission, and near-term objectives of the IVI program, the committee believes it is critical for the program to be well focused and for the roles of government and industry to be clearly defined.**

Resource Allocation

DOT staff made persuasive arguments for inclusion of the nonpassenger vehicle platforms in the program despite concerns that limited program funds may be spread too thin as a result. With more controlled operating environments, professional drivers, and more limited liability risks, at least for public entities, the commercial and transit vehicle platforms in particular may offer opportunities for rapid deployment and evaluation of new technologies. Nevertheless, the committee was not fully convinced that in all cases the experience thus gained could be transferred to passenger vehicles. This determination must be made on a technology-by-technology basis. The committee would welcome more information on which specific technologies and services are most likely to have relevance and possible application to other vehicle platforms, particularly passenger vehicles.

Setting of Milestones and Targets

Several committee members noted the absence of milestones and targets in IVI program materials to serve as a basis for judging progress. In particular, **DOT should set targets with respect to the crash reduction potential of particular technologies, and establish milestones for monitoring progress toward the deployment of those technologies and the realization of safety benefits.** The latter are particularly important because achievement of full safety benefits is likely to take many years given the slow turnover in vehicle fleets.

Focus on Crash Avoidance

The major focus of the IVI program is on technologies that help the driver avoid collisions. This is an important goal, and DOT staff made a strong case that substantial advances could be made in reducing highway fatalities and injuries if effective technologies were deployed. The committee applauds DOT efforts to keep the IVI program focused. However, certain IV technologies also have important potential application for improved crashworthiness and injury mitigation once crashes have occurred. Some committee members urged that more provision be made in the program for these applications. An example is adaptation of sensor mechanisms in collision warning systems to provide earlier information for airbag deployment or safety-belt tensioning in a crash, thereby helping to reduce airbag aggressiveness and enhancing the effectiveness of safety-belt operation. Moreover, motorists would likely accept such applications more readily than those aimed at collision avoidance— and thus the safety benefits would be more rapidly achieved— because improved operation of occupant protection devices would be largely invisible to drivers and other vehicle occupants.

Involvement of New Players

The revolution in data processing for automotive applications expands significantly the pool of problem solvers who can contribute to improved motor vehicle safety. Important talent can come from new industrial sectors (such as software development) and academic and federal research agencies different from those which have traditionally been engaged in transportation research. An important role for government is to facilitate the involvement of these new participants in appropriate partnership arrangements and other relevant program activities, and especially to promote their understanding of the problems involved in improving the safety of motor vehicle travel.

Program Presentation

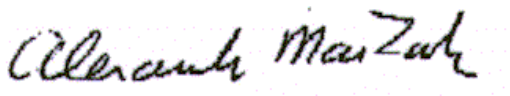
Several committee members noted that program materials, as currently written, give the impression that the IVI program is largely technology rather than needs driven. At the meeting, National Highway Traffic Safety Administration staff presented crash statistics for the major crash categories (e.g., intersection collisions, rear-end collisions, roadway departures) as support for technology-based countermeasures. More detail is needed by specific IV technology area to help set priorities and make the case for particular technology investments. The committee urges that more of such material on problem identification and expected safety benefits be included in future revisions of IVI program documents.

NEXT STEPS

The committee looks forward to discussing the comments and suggestions presented in this report at greater length with DOT program staff and other stakeholders. At its next meeting, the committee hopes to have an opportunity to view several of the emerging IV technologies in live demonstrations on test tracks and on the highway. It also looks forward to discussing the government-industry response to the proposed IVI Governance Recommendation submitted by ITS America following the first committee meeting, and to the results of the partnership awards for field tests that will be announced this September. The committee hopes to discuss the implications of these major milestones on program priorities, design, and resource allocation.

The committee thanks the JPO for the opportunity to comment on the IVI program in its formative stages, and looks forward to a continuing and constructive relationship as the program moves forward.

Sincerely,



Alexander MacLachlan
Chair, Committee for the Review of the Intelligent Vehicle Initiative

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FOOTNOTES

[1] The PNGV program is a cooperative research and development program between the federal government and the United States Council for Automotive Research, representing the automobile industry. When the program was launched in 1993, the cooperative partnership approach was viewed as an alternative to more traditional "command and control" regulatory measures, which in this case would have involved mandated increases in corporate automotive fuel economy (CAFE) standards. The goal of the PNGV program is to develop technologies for a new

generation of vehicles that could achieve fuel economies up to three times those of comparable 1994 family sedans without compromising performance, size, utility, safety, emissions requirements, and cost. The program is focused on the development of concept vehicles by 2000 and production prototype vehicles by 2004 (BEES 1999, 1). Federal funding directly related to PNGV exceeds $200 million annually (BEES 1999, 58).

[2] In the context of the IVI program, enabling research refers to the necessary research that makes possible (i.e., enables) the development and more rapid deployment of IV technologies. Examples of such research are provided later in the text.

[3] Human factors is an interdisciplinary field of study that attempts to apply experimental findings from behavioral and life sciences to the design of machines, operations, and work environments so they match human capacities and limitations (Chapanis 1959, vii). The aim of human factors research is to optimize the human-machine interface in order to reduce human error and accidents and increase comfort and efficiency. Human factors research is also concerned with behavioral responses to system complexity. Too much complexity can overwhelm the operator. Too little complexity (i.e., highly automated systems) can result in operator complacency and inattention.

[4] Several large-scale assessments of the effects of antilock brake systems (ABS) on crashes, reported by the National Highway Traffic Safety Administration (Hertz et al. 1995a, 1995b) and corroborated by separate studies conducted by the insurance industry-funded Highway Loss Data Institute of the Insurance Institute for Highway Safety (IIHS 1995), found mixed effects for different crash types and no significant overall net crash reduction for ABS-equipped vehicles. An automobile industry-sponsored study (Lau and Padmanaban 1996) found lower crash rates for ABS-equipped versus nonequipped passenger vehicles, but no measurable difference in fatal crash rates.

Abbreviations

BEES	Board on Energy and Environmental Systems
IIHS	Insurance Institute for Highway Safety
JPO	Joint Program Office
NHTSA	National Highway Traffic Safety Administration

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