6.0 Fundamental Advanced Research

6.1 Introduction

This white paper deals with the area of Advanced Research. The following definition of Advanced Research is from the Transportation Research Board Special Report 261 (TRB, 2001) and is the working definition used for this report:

Research that involves and draws upon basic research results to provide a better understanding of problems and develop innovative solutions. Sometimes referred to as exploratory research in order to convey its more fundamental character, its broader objectives, and the greater uncertainty in expected outcomes compared to problem-solving research.

The TRB Special Report 261 also recommended increased funding and an increased emphasis to advanced research projects at the Federal Highway Administration (FHWA). Planned authorization of appropriations to the Transportation Research Bill[2] finds that the federal investment in R&D should be properly balanced between short-term applied research and long-term fundamental research, as well as between research areas including materials and structures research, operations research, and human factors and policy research. Also, it creates a new Exploratory Advanced Research program (Section 502(d)) to address recommendations of the TRB and others that the FHWA's R&D program should focus on fundamental, long-term research. Also, a recent statement by Vernon J. Ehlers (Chairman, Subcommittee on Environment, Technology, and Standards Committee on Science) on the introduction of the Surface Transportation research and Development Act of 2003 calls "on the U.S. Department of Transportation to take the lead in carrying out fundamental, long-term research to achieve breakthroughs in transportation research."

There is support for the expansion of the FHWA's Advanced Research Program at high levels of government. Also, there are planned increases to the funds allocated to advanced research. The FHWA's Advanced Research budget has averaged at about $2 million per year. The proposed Transportation Research Bill increases this funding in 2004 to about $7 million per year[3].

A recent White Paper by Mitretek (Mitretek, 2003) presents a summary and review of the FHWA's Advanced Research Program and its accomplishments over the past 20 years. In addition, this paper expands on the definition of Advanced Research as presented in TRB's Special Report 261. Advanced Research types of projects have been conducted by the FHWA for some time. Going forward, there will be an emphasis on developing an integrated and more expansive Advanced Research Program. Also, the procedures for identifying and selecting Advanced Research projects will be modified relative to FHWA's current process.

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[2] Section by Section Analysis. Science Committee Transportation Research Bill. November, 19, 2003.

[3] This information is out of the Surface Transportation Research and Development Act of 2003. Published November 19, 2003. The Bill shows funding for advanced research going up to $10M in the second year, and $15M per year thereafter.

This White Paper focuses on advanced research as applied to the highway safety problem areas. As can be seen in the recent publication in Public Roads, A Decade of Achievement (Livingston, Mills & Oskard, 2002), the FHWA's Advanced Research Program has focused on both the areas of Operations and Safety, and Infrastructure. The Operations and Safety advanced research has been in the areas of: operations research; sensor applications; artificial intelligence; and analytic tools.

As presented in the Mitretek White Paper on Advanced Research, one of the major changes in the near term for this program is the manner in which Advanced Research projects are nominated and selected. Selection of Advanced Research projects are to proceed from the identification of knowledge gaps and external (to TFHRC) input to the program. One of the major sources of information on knowledge gaps and research directions used in the preparation of this paper, are the conference proceedings from the Safety Research Agenda Planning (Research & Technology Partnership, 2002)..

This conference focused on identification of critical research needs for:

- Run off road;
- Human Factors;
- Intersections;
- Work Zones; and
- Intelligent Infastructure Initiative

From an advanced research perspective, the discussions and recommendations presented in the conference proceedings can be grouped into three major areas:

- Understanding and prediction of driver behavior. This theme was evident throughout the discussion of the various research areas and proposed research efforts.
- Better collection of data to support problem identification and evaluation of treatments (e.g., countermeasures). Also, associated with this theme was the development of analytical tools to consider the impact of specific designs/countermeasures on safety.
- Application of advanced technology to transportation. This was evident both in terms of discussions of countermeasures (e.g., Intelligent Infrastructure treatments) as well as advanced techniques for collecting and analyzing data.

The above grouping is meant to guide the discussion of advanced research and the proposal of a series of research efforts to propose in this White Paper. Advanced Research is problem oriented as is any other research activity conducted by the FHWA. However, some of the defining features of advanced research may include:

- Long-range programmatic research. Advanced Fundamental Research is not a one-shot study effort. This type of research is multidisciplinary and may require years of efforts for results to bear out. Furthermore, specific research conducted under an advanced research effort may not lead to the expected outcome. That is, the model, sensor, or specific technology may not be appropriate or applicable to the problem at hand. One may not learn this after considerable effort has been expended.
- Application of advanced technology or new theoretical models to address safety problem areas.

- Cross-cutting in nature. Advanced research efforts may support understanding of problems across a range of safety problem areas (e.g., run off road, intersections) as well as result in countermeasures that that can be applied across a range of problems.

The following section presents specific research topic areas for Advanced Research. The selection of these specific research topic areas were in large part driven by the recommendations and suggestions presented in the proceedings for the Safety *Research Agenda Planning Conference*. In addition, limited reviews of research and technology were conducted. It is assumed that if a given research topic or area is deemed of interest, additional research will be need to be conducted to refine the research topic. For example, proposed research efforts may include the study and application of new technology, i.e., new developments in artificial intelligence, nanotechnology, advanced data mining techniques and procedures, and advanced sensor technology. These efforts will require additional collaboration with other government laboratories and organizations as well as detailed technology reviews.

One of the guiding principles in developing the proposed research topics was to focus on a few areas that had a potential for high pay-off in the long run and that would be cross cutting in its effects. That is, a given successful Advanced Research project could benefit our understanding and amelioration (or elimination) of safety problems across a range of areas, i.e., intersections, run off the road, work zone, etc.

6.2 Specific Research Topics

Suggested Research Topics/Studies

Category	Project Title	Type of Research	Likelihood of Success (1-5 Scale)	Duration (Months)	Estimated Cost
1. Understanding the Driver	**ADV 1a:** Development of a Driver Modeling Structure	Advanced	Very High 5	24	$2M
	ADV 1b: Development of a Prototype Driver Model	Advanced	High 4	36	4M
	ADV 1c: Development of a Driver Model	Advanced	Moderate 3	60	15M
2. Data Collection/ Analytical Tools	**ADV 2a:** Evaluation of Advanced Sensors and Data Mining Techniques	Advanced	Moderate 3	36	4M
	ADV 2b: Development of Safety Decision Aids for Planners	Advanced	Moderate 3	36	5M
3. Advanced Technology for Countermeasures	**ADV 3:** Evaluation of Nanotechnology for Safety Countermeasures	Advanced	High 5	12	250K[4]

Research suggestions from R&T Partnership Steering Committee

If a driver model is developed, research into whether it should concentrate on group rather than individual behavior. Other suggestions include: 1) A program that defines and validates crash "surrogates" so that they can be used in future safety assessments and evaluations (perhaps related to "advanced sensors"), 2) Fundamental research into methods for evaluating the crash-related casual effects of intervention – given the difficulties of having the ability to conduct randomized experiments, and 3) Use of forensic approaches to establishing detailed reconstruction of events – high-tech field data collection techniques, perhaps image processing and high performance computations for reconstructing events.

Response from White Paper authors

1. The White paper included doing a requirements analysis and design of a modeling architecture. However, the tone of this White paper was in the development of a driver model

[3] **Note: The proposed $250K is for a project to develop a nanotechnology research program at FHWA.**

for individual behavior. This is a research question that should be addressed in the requirements phase of the work.

2. The development of safety related measures that can be used to predict crashes has been going on for some time. These measures are frequently referred to as safety surrogates. The report by Campbell, Lepofsky and Bittner (2003)[5] discusses safety surrogates in detail and data collection methodology to support the development of more valid and reliable safety surrogates. Their report proposes a large scale, multi-year data collection set of efforts.

The issues with developing valid and predictive safety surrogates can considered from two perspectives. First, an analytical framework needs to be developed to guide the research. Another term for analytical framework would be a theory. The second major challenge has been that one wants to predict the occurrence of crashes as a function of a host of independent variables. Crashes though numerous are rare events when one considers the total number of miles traveled (exposure). So research attempting to correlate some form of behavior and other factors to crashes requires a large amount of data. Also, the data needs to be collected at a fine level of resolution and it needs to be very reliable.

This white paper focuses on the development of an analytical framework or model. Numerous papers on highway safety cite human factors as a major causal factor in the occurrence of crashes. These human factors issues range from driver distraction, inattention, workload, or other theoretical constructs used to try to explain the behavior of the driver under conditions that result in a crash. A driver model as proposed in this paper would serve to develop an analytical framework that can guide research into understanding and predicting driving behavior. Also, the framework would aid research in selecting measures for predicting crashes or the risk of a crash.

The focus of this section of the White Paper was on advanced research. So the author chose to focus on the development of the model rather than on the development of correlational studies to define and validate safety surrogates. This is perhaps the more difficult side of the problem, but in the long run may lead to greater payoff.

Understanding the Driver

The report by Campbell, Lepofsky and Bittner (2003) presents a review of current and projected highway safety issues. They observed that "the interrelationship of driver performance and behavior with roadway design and traffic conditions to affect the risk of collisions and casualties is largely an unknown area, despite the fact that driver behavior is widely believed to be responsible for most collisions." Reasons cited for this lack of understanding of driver behavior include a lack of detailed information on driving behavior and driving errors. That is, sufficient detailed an reliable data have not available to fully understand the relationship among multiple factors responsible for collisions and casualties. One of the factors most frequently cited as being responsible for most collisions is driver behavior.

[5] This report was published and made available to this author after preparation of the first draft of the White Paper on Advanced Research.

The driver, vehicle, highway environment is complex and there are host of factors, and the interaction of those factors, that need to be considered when conducting research to understand the factors responsible for collisions. One of the best tools to use in such complex situations are analytical frameworks or models. Such an analytical framework would serve to guide long-range research that can ultimately result in a model can predict driver behavior under a wide range of conditions. Development of such a model would go hand in hand with the collection of detailed driving performance data. Data collection that is guided by an analytical framework or model is more likely to be of use than data that are collected because we now have the technology.

The end goal here would be to develop a model that would support design and evaluation of countermeasures. The FHWA has worked on developing driver models for some time. These models have been relatively simplistic as those embedded in traffic microsimulation models. More complex driver models have been developed for the IHSDM project. However, development of driver models has not been a major focus area for the FHWA R&D efforts.

Why Develop a Driver Model?

In general terms, models are abstractions of reality. A blueprint for a building is a model. Furthermore, blueprints for buildings will "model" different aspects of a building – the plumbing, electrical wiring, etc. This type of model is used to design a specific building for a specific purpose. If we develop a good model (blueprint), we will have a sound, functional building that meets the requirements and all of the components work together (the elevator shaft will not be located on top of the water main, etc.). As with all models, the blueprint for the building will not be perfectly identical to the building that we build. If we do a good job of following the blueprint and follow good building practices, it will be close enough.

Models help to define a problem and define requirements. In the area of research, models can help to organize the research activities (e.g., specific experiments or data collection efforts that need to be conducted) and help us to determine where we have knowledge gaps. Models serve as an organizing principle.

Models can be used to make predictions and support system development. For example, NASA has a System-Wide Accident Prevention Program. The goal of this multi-year program is to foster the development of new technologies to reduce aviation accidents. One of the specific technologies being developed is a synthetic vision system. To support this program, the Human Error Modeling (HEM) element is investigating the application of human performance models to study the types of errors operators could make when using new technology such as synthetic vision. (Leiden, Laughery, Keller, French, Warmick & Wood, 2001).

So the development of a driver model can

- Help in focusing our research efforts. If we have a relationship or function in the model and there are no data to support the function, it will be very evident. The model won't run or we will need to insert some "engineering estimate" or simplification.
- Help us to integrate our research efforts. For example, we need to tackle intersection collisions, work zone related crashes, and run off the road crashes. However, the human element in terms of risk taking, choice behavior, perception, and so forth is the same across

these different types of crashes. Also, models can help us integrate results and support development of a knowledge base.

- Help us to design better systems. If we have a good working model of the driver, different design options for intersections (for example) could be tested well in advance of building the actual system. For example, if we have a good model that incorporates prediction of human error, we may be able to rule out designs that may prove to be unsafe.

6.3 Knowledge Strongholds

Significant advances have been made in the area of cognitive modeling. There are a diverse number of models currently in existence. The reason that there exists a diverse set of cognitive models has to do with the level of fidelity that perception, attention, working memory, and decision making are addressed by the individual modeling architectures (See Leiden et al, 2001, for a brief review of relevant cognitive models).

Existing cognitive models have been applied to the driving situation. For example, Salvucci employed the modeling architecture of ACT-R (Adaptive Control of Thought- Rational) to model driver distraction from cognitive tasks (Salvucci, 2002).

The existing cognitive models present the opportunity to build modeling architectures for driving by re-using existing models. This area is reasonably mature and computational frameworks that incorporate built-in, well tested parameters and constraints on human cognitive and perceptual-motor abilities are available.

There is also a large volume of driver performance data in existence. However, determining the degree to which existing driver performance data could support model development would need to be accomplished at a later time. The research program outlined by Campbell, Lepofsky and Bittner (2003) presents a comprehensive and extensive set of field data collection studies. This project presents a potential for providing a rich source of driver performance data. However, data to support the development of behavioral models generally works best when the data collection efforts are designed in support of model development. It is likely that additional data collection would be needed to develop a comprehensive driver model.

6.4 Knowledge Gaps

Based on a limited review of the literature, it appears that the application of cognitive models to the driving situation has been limited. Furthermore, the validation and calibration of the models have been frequently done by comparing model performance to performance in high fidelity driving simulators. This can present an added level of uncertainty. That is, ultimately one would want to develop models of the driver that predict performance on the road. High fidelity simulators are also models of the real world and thus have limitations; however, the limitations are in terms of how the vehicle/driving environment are modeled and not the driver's cognition and decision making. The use of simulators in developing computational models is probably a good idea; however, ultimately the computational model needs to be tested against real-world driving.

The limited review of cognitive modeling indicates that there does not exist a rigorous model of multitasking. This will need to be an area of research given that the driving task does indeed entail multitasking. Also, as additional technologies get added to vehicles and more information is provided to the driver from the infrastructure, the driving task is likely to require more multitasking than it does so currently.

Though there is a large volume of data on driver performance, it is likely that much of these data may not support a modeling effort. It is not the case that the available data are not useful, rather that it may not be at the level of resolution needed for modeling studies. This is an empirical question that will need to be dealt with if one were to move forward on large scale driver modeling effort.

As was mentioned in the proceedings of the *Safety Research Agenda Planning Conference*, the FHWA has developed a driver model for the IHSDM. This driver model focuses on a narrow question – i.e., speed control through a curve. This is not unusual in the modeling world. That is, a specific question is asked and a specific modeling solution is developed. Generally, the state of the art in driver models is that specific narrow models may be available; however, general models that can be employed across a range of problem areas are not available (this is based on a limited review of the literature).

The above also presents a limitation or challenge to the development of a comprehensive driver model. That is, models are built for a given purpose. The development of very general driver model will likely require the development of an overall modeling architecture. Furthermore, since the modeling effort will need to be supported by empirical studies (e.g., simulation studies, field data collection, field experimental studies) an overall research program will also need to be developed. The research program will need to consider data collection efforts being conducted by other programs (e.g., Campbell, Lepofsky, and Bittner).

It is suggested that the overall driver modeling program be broken down into three major components:

- Development of a driver modeling structure;
- Development of a prototype driver model; and
- Development of the general driver model.

6.5 Research Recommendations

Driver Model Development

It is proposed that the development of a driver model be conducted in a structured series of steps. After completion of each step, the program should be reviewed and the program should be adjusted based on results of completed work. The proposed effort will be conducted over several years and therefore one should take advantage of new developments in cognitive modeling, modeling software, and computing platforms.

Development of a driver modeling structure

Comment from R&T Partnership Steering Committee

This proposed study and the proposed Human Factors program are similar and should be combined into one research program. Another question that comes up is will any driver model be capable of predicting “driver errors” rather than just “average driving behavior”? The research should be coordinated with F-SHRP research and current NHTSA research.

This will be *high-risk* research (which fundamental research should be). But this idea needs external review by experts who will not benefit from the program.

Response from White Paper authors

1. Good points regarding predicting driver error versus average driving behavior. The White presented the development of a driver model within the context of a research program. I see the driver model to be an analytical framework to help direct research and if successful to be used in a predictive mode. The ultimate goal would be to predict driver behavior that leads to crash scenarios. Therefore, the model would need to be able to predict “errors”.

2. I don’t understand the comment “needs external review by experts who will not benefit from the program”. It appears to me that if the program is successful anyone who uses our highways will benefit.

Under this task an overall architecture for the driver model would be developed. This will entail identification of requirements for the modeling program. That is, what is to be modeled, under what conditions, and the types of measures that will be estimated. This would most likely require the use of the System Engineering Process and associated techniques and procedures for capturing the system requirements and design. A tool such as the Unified Modeling Language (UML) may prove useful for this project. The to-be developed driver model will be a system, and such following good system engineering development process will support the development of a robust model.

Under this project work would also be conducted with respect to review and evaluation of existing cognitive models and other developments in the modeling field. The definition of requirements and system design will drive the model development. However, in parallel with this activity a solid review and assessment of the modeling field will expedite the process.

Problem Statement
Development of a robust and general cognitive driver model will require the development of an overall modeling architecture. Also, review and evaluation of existing cognitive models will be needed. The results of this project will be a detailed model design that can be used to develop a prototype driver model and an overall research program for the driver model program.

Method / Approach

This task will entail the use of a systems engineering approach and selected tools for developing the modeling architecture. The UML represents a type of tool that may be used to capture the driver model (requirements and system design) at a detailed level. The project will also entail review of the literature (with respect to the content area of safety, cognitive models, and other modeling techniques and tools) and review and evaluation of models. It is anticipated that models will actually purchased and subjected to detailed review.

Project Duration

The estimate of two years is to allow for the multiple design reviews that will be needed. The proposed driver model will not be a trivial system and such will require systematic review and assessment as it is being designed. Also, this task will require extensive interactions with researchers in the modeling community as well as those conducting traditional driver performance and safety research. This level of collaboration is also a factor for the proposed project duration.

Project Title: Development of a Prototype Driver Model

Before moving on to develop a full blown and general driver model, a prototype model would be developed. This may entail focusing on a specific safety problem area (e.g., intersections) and developing working models. Also, the development of the prototype model would entail validation of the developed model. Therefore, this task will also include the conduct of experiments or other data collection efforts.

Problem Statement

Embarking on the development of a complex and general driver model will be a new endeavor for the FHWA. One way to minimize risk is to develop a prototype model that exercises the capabilities envisioned for the full model; however, focused on a more narrow domain. Based on the crash statistics (GES, 2002) and the results of the *Safety Research Agenda Planning Conference*, the area of intersections may be a good candidate for the prototype model.

The development of the prototype model will give the research team experience in implementing a modeling architecture. Also, development of the prototype model will feed back to the overall model design (e.g., propose changes based on what works and what does not work). In addition, procedures for validating the model will be developed and tested. The developed validation procedures and datasets can also be used in the development of the full-scale model.

Under this task modeling software will be developed. Even if this developed software (the prototype) is not totally re-used for the development of the full driver model, there will be an ultimate savings. Given the long range duration of this effort, we need to be aware of new developments in modeling software and more specifically computational cognitive models. It may be the case that better models and modeling tools will be made available once the project goes into the phase of developing the full-scale driver model.

Method / Approach
This project will entail software development of the driver model. Also, research will be conducted to support model calibration and validation. The specifics of the research efforts will depend on the focus domain for the prototype driver model (e.g., intersections, run off the road, work zones).

Project Duration
The project duration is anticipated to be about 3 years. This will be a software development effort that will require a significant amount research. The availability of existing computational cognitive models (e.g., ACT-R) will facilitate this process. However, to date there have been very few modeling efforts of this magnitude in the driving domain. Also, the model development will be conducted in parallel with empirical research efforts for collecting the data needed to calibrate and validate the model. It is also anticipated the prototype model will be a useful model for the chosen domain.

Project Title: Development of a Driver Model

This project would entail development of the full-scale driver model. The products of this project would be the code for the driver model, documentation (user and system documentation), and reports and databases documenting the results of the model validation efforts.

Problem Statement
The objective of this project would be to develop a computational driver model that has been validated. This will be one of the major challenges in this effort given that this will be a relatively complex model used to predict performance under a wide range of conditions. A detailed model validation plan will need to be developed as part of this effort. As discussed earlier, this is a research program that will entail model development as well as the conduct of empirical studies for calibration and validation of the model.

As this project spans several years, we will need to ensure that up-to-date cognitive models and modeling techniques are employed. Rapidly evolving technology or theory can present significant challenges to efforts of this sort.

Method / Approach
This project is similar to that proposed for development of the prototype model. However, the scale will be much greater in terms of the domains to be modeled. That is, this project will entail model development and testing, conduct of empirical studies to support the modeling effort. This project may also entail a bit of theoretical work. As was mentioned earlier, currently robust models for multitasking do not exist. Either as part of this effort or in collaboration with other researchers in the area, multitasking models for this effort will need to be developed.

Project Duration
This project is anticipated to be a 5 year project. This will be a major modeling and research program. In principle, well as validation effort, a significant portion of the driver and safety research conducted by the FHWA could be aimed at supporting this effort. Research would be

conducted to answer specific research questions and provide input to guidelines and other design support efforts. At the same time the research would support the model development as

Data Collection/Analytical Tools

Another major area or theme from the *Safety Research Agenda Planning Conference* was the need for better safety data collection and analysis tools. This was in terms of data for identification of problems (e.g., "what is the relationship of the traffic volumes at intersections and safety', pg. 26) as well as in the development of tools for planners (Analytical tools – in models for traffic engineers and planners to consider the safety consequences of intersection safety and design", pg. 27).

The report by Campbell, Lepofsky and Bittner (2003) propose the development of research tools and methods as one of the three major focus areas for the F-SHRP Safety Plan. Campbell et al present a review of vehicle-based as well as site-based instrumentation for the collection of driver and vehicle behavior. Most of the studies reviewed by Campbell et al are still in the early stages and a significant amount of data collection or analysis has not been conducted to date. Additional research aimed at developing new data collection tools will need to be coordinated with above efforts.

For this area, two research projects are suggested:

- Evaluation of advanced sensors and data mining techniques; and
- Development of safety decision aids for planners.

Evaluation of advanced sensors and data mining techniques

Comment from R&T Partnership Steering Committee

The expected benefit of this proposed project is unclear. One potential use is to develop surrogate measures of safety. In setting the requirements for research in this area, one should also attempt to anticipate future issues and thus future data needs. There's no mention of data collection and analysis tool development proposed in F-SHRP.

Response from White Paper authors

The white paper focused on evaluation and development of technology. I am not sure that I want or need to address the issue of safety surrogate measures. The notion of safety surrogates has to do with a hypothesized relationship between a set of measures (e.g., driver behaviors, traffic conditions,) and the probability of a collision. Development of safety surrogates goes well beyond the application of new technology for data collection. The idea of safety surrogates is probably more relevant to the discussion of the development of a driver model.

The FHWA has on-going work in the area of sensors and data mining techniques. The report by Mitretek on Advanced Research lists over 22 related projects (in the areas of Automated real-Time Use of Information, and Improved Data Quality). The FHWA has also conducted research in such areas as automatic data collection of vehicle trajectory through the SBIR program.

Nevertheless, one of the major themes to come out of the *Safety Research Agenda Planning Conference* was the need for better data collection techniques and tools along with analytical capabilities.

In a related project the National Highway Transportation Safety Administration (NHTSA) has funded the System for Assessment of the Vehicle Motion Environment (SAVME). This project has been going on for over 10 years. This is a very extensive program to develop data capture and analysis techniques of potential safety related measures. The SAVME technique involves imaging motor vehicles in normal traffic from specialized video cameras on roadside towers so as to create permanent track files. The track files quantitatively capture the vehicle trajectories and inter-vehicular clearances that prevail in normal driving. The first production runs of empirical data for this project were reported at the 2001 TRB meeting (Ervin, Bogart & Fancher, 2001; Ervin, MacAdam, Vayda & Anderson, 2001). The analysis entailed evaluation of conflicts in a vehicle string and suggestions for developing crash warning systems. Lessons learned and results from the SAVME project could provide input to this proposed effort.

For this proposed research it suggested the focus be on developing, testing, and evaluating methods for safety data collection and analysis. That is, this project would not focus on developing a product per se. Promising technologies and methods identified through this research would then move forward to applied-tools development type of efforts.
Some critical issues for this effort will entail development of clear requirements for data collection. Data are generally collected for a specific purpose (e.g., to test a hypothesis, fill in the gaps in a performance taxonomy) and the purposes one has in mind will impact what is collected, where it is collected, the level of resolution, and so on. This tends to be one of the major challenges for developing general tools and techniques for collection of data for complex areas such as those related to highway safety.

Problem Statement
Conduct research to develop advanced techniques and procedures for collecting and analyzing safety related data. This effort would support research for problem identification (e.g., identifying "unsafe" intersections and relevant performance data) as well as evaluating countermeasures. One of the major challenges will be ensuring that the data capture and analysis requirements across the safety program are met (e.g., intersections, run off the road, work zones).

Method / Approach
The effort would entail developing data capture and analysis requirements up front. Given the identified requirement, existing or developing technologies and methods would be reviewed. In order to develop specific requirements that can be implemented outside of advanced research, it is suggested that limited testing and evaluation be conducted in the field. That is, conduct a research effort at a demonstration and testing level. Initial focus for this effort may be directed to the area intersections. This area presents perhaps the highest potential for pay-off in terms of having an impact on safety performance. Again, this effort would not directly impact safety performance, but rather would provide tools to efforts investigating safety problems and developing and testing countermeasures.

Project Duration

This effort will entail a significant up front effort in developing a clear set of requirements. Also, this effort will entail technology evaluation and testing as well limited field tests / demonstrations. At the same time this effort is not envisioned to be a 10+ year effort as the SAVME program. If a set of specific products and tools are to be developed, they should be developed outside of the Advanced Research effort. The results of this effort should translate in a set of system requirements and design that can be implemented as tool/product development effort.

Development of safety decision aids for planners

Comment from R&T Partnership Steering Committee

This is probably more “applied” rather than fundamental research. While need is probably there, more justification and details are needed, along with more on the relationship to current work such as IHSDM, IDAS, NCHRP 8-44, and other initiatives.

Response from White Paper authors

I think that there are some fundamental issues that need to be resolved in this area. The idea for suggesting this area of work came from the Safety Research Agenda Planning Conference report. Also, experience with the use of such models as IDAs suggests the need for research in this area.

NCHRP 8-44 does focus on the development of estimation techniques or models for fatal and injury crashes. The study is employing simultaneous negative binomial models. Furthermore, the type of model being developed is not sensitive to network improvements typically identified in transportation plans[6]. This study is on-going and reports are not currently available and so a more detailed assessment can not be made at this time. However, if additional research is conducted in this area one will need to coordinate with NCHRP 8-44.

IDAS does support decision making for planners. It fits well in to the planning process and uses the results of planning models to estimate the impact of a range of ITS improvements on a network. The safety module in IDAS is extremely simplistic even for the level of analysis that it is used for. The reason for the safety module being simplistic (considers facility type and level of service) is that adequate theoretical models have not been developed to consider safety within this type of modeling environment. Also, there are not sufficient data available to develop robust relationships among highway and traffic variables and the associated probability of a crash.

One of the themes out of the *Safety Research Agenda Planning Conference* was the development of tools to “support traffic engineers and planners in considering the safety consequences of intersection safety and design” (pg. 27). The following quote from the conference proceedings expands a bit on this theme.

[6]These conclusions are based on review of a presentation on NCHRP 8-44 given at the Safety Conscious Planning Leadership Conference, 2003. This study is on-going and results have not been published.

“a justification for the need for this is that there is a lot of development and re-development going on in our urban and suburban areas, and a lot of decisions need to be made on where you put intersections and what type of intersections do you put in. So, we feel we could help traffic engineers and planners explicitly consider safety in that decision-making process if we develop the right tools and models.” (pg. 27)

The FHWA has a long history of conducting research and development for tools used by engineers and planners (e.g., CORSIM, IDAS, Quickzone). However, these types of tools do not address the safety area in sufficient detail to support the types of decisions indicated in the above quote. It is suggested that an Advanced Research effort be conducted that ultimately leads to the development of decision support tools.

Though the end product of this proposed research effort are tools that can be used in a applied setting, significant fundamental research needs to be conducted to develop safety types of modules that provide valid safety impacts. Research needs to be conducted to define the range of variables to consider in estimating safety impact for models to support the planning process. As mentioned earlier, models such as IDAS have very simplistic safety modules. This is due to the lack of valid and reliable models (e.g., mathematical models) and the data to support the models.

Problem Statement
Based on input from the Safety Research Agenda Planning Conference and limited and informal discussions with planners[7], it appears that this may be a real need that should be addressed in the near-term. The FHWA has embarked on a related project entitled *Impacts Analysis Process Model and Tool Development*[8]. The objective of this project is to develop a work zone impacts analysis process (algorithm) that will assist transportation professionals in the selection of work zone impacts mitigation strategies.

This proposed project would focus other areas where decision support is needed (e.g., intersections). However, it would also coordinate and share information with other related efforts such as the above cited Work Zone effort. In addition, the proposed research effort would be coordinated with other related projects such as NCHRP 8-44 “Incorporating Safety into Long-Range Transportation Planning”.

This project would ultimately result in a model usable by engineers and planners. It is being proposed as an Advanced Research effort since a significant amount of research and analysis will need to be conducted in order to develop a tool that explicitly considers safety in the decision-making process of planners and safety engineers.

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[4] Given the time frame of the project interviews or discussions were not conducted with Public agency personnel involved in the decision making process that were indicating the conference proceedings. Rather informal discussions were held with personnel at Cambridge Systematics who provide support to State and local Government agencies. If this effort is selected for going forward, obviously systematic interviews and discussions with the end users will need to be conducted.

[5] This project is a Task Order under Contract No. DTFH61-01-C-00181. Technical Support to the FHWA Office of Operations.

Method / Approach
This type of project will entail review of the process that planners and engineers employ in their projects. We will need to ensure that the decision support tools that are developed clearly support their jobs. So the methodology will entail process review and requirements definition. Since the objective is to develop a decision support tool (some sort of software system), a structured engineering system design process should be followed. Also, tools for support in designing the system should be employed (e.g., UML or some other type of system design tool).

As part of the requirements definition, specific areas for applying the developed decision support tool should be identified. For example, based on the input from the Safety Research Agenda Planning Conference and crash statistics (e.g., GES 2002), intersections may be a good candidate for the initial decision support tool.

Project Duration
This project is proposed with 36 month project duration. It is anticipated that it will take approximately one year to do the requirements analysis, survey and collect data, and develop a design of the decision support tool. Year two will entail rapid prototyping and testing of the decision support tool. And finally, year three will entail development of the tool for wider use and testing.

Advanced Technology for Countermeasures

This area of research is suggested based on review of the current project areas for Advanced Research. The FHWA Advanced Research projects are summarized in Mitretek's report on *FHWA Mission-Oriented Advanced Research: Past-Transition- Future.* Also, the article entitled *A Decade of Achievement* in the November/December 2002 edition of Public Roads presents additional summaries of the Advanced Research projects.

A significant portion of this research is aimed at employing advanced technology and methods to solve transportation problems. The current FHWA Advanced Research program includes the area of nanotechnology. The Mitretek report on Advanced Research lists 8 projects in this area with level of funding of $430K and $704K ($150K of this funding comes from State Pooled Fund), for FY 2002 and 2003, respectively.

The area of nanotechnology has been receiving a tremendous amount of attention and funding during the last few years. The National Nanotechnology Initiative (NNI) was initiated in 2000 and provided a budget of $422-million in 2001. This was a 56% increase in nano spending from a year earlier (Stix, 2001). In November 2003, the 21st Century Nanotechnology Research and Development Act (bill S.189) was passed. This bill would authorize $3.7 billion over the next four years for federal nanotechnology programs.[9]

The National Science Foundation predicts that nano-related goods and services could be a $1 trillion market by 2015, making it one of the fastest-growing industries in history. This would be

[6] Nanotechnology bill called "historic". In GovExec.com, December 1, 2003.

larger than the combined telecommunications and information technology industries (Ratner & Ratner, 2003).

The area of nanotechnology is relatively new. In the late 1970s Eric Drexler developed concepts for molecular nanotechnology at MIT. In 1981 the first technical paper on molecular nanotechnology was published by Drexler (Mulhall, 2002). At the same time, Goodyear has incorporated micro sensors into tires that indicate when they need replacing. Corrosion-resistant nanoparticle coatings are also being applied to the hulls of Navy ships to reduce drag, increase speed, and reduce rust (Uldrich & Newberry, 2003). Though this is a new area and significant research and investment are needed to meet the promise of what this technology has to offer, there are currently practical applications in place.

Evaluation of nanotechnology for safety countermeasures

Comment from R&T Partnership Steering Committee

Unclear to reviewers what nanotechnology is or could possible do for safety – more clarity or examples needed. If this is "technology looking for a safety problem," are there other such technologies that might be better or equal?

Response from White Paper authors

The FHWA is currently conducting small-scale studies and projects in the area of nanotechnology. The author suggests that the FHWA develop a coordinated and long range program in this area. In order to realize significant benefits from the application of nanotechnology to the highway safety area, an integrated and long range program is needed. This is not an example of a technology in search of a problem but rather a suggestion that this technology be more fully evaluated and used if it appears that it can be employed in highway safety related applications. The area of nanotechnology is at an early stage of development and it is difficult to predict all of the potential applications at this time.

Under this category a single project is being proposed. Given the increase in funding and interest in the area of nanotechnology over the last few years, and the limited amount of work in this are by the FHWA Advanced Research program, it suggested that an initial study be conducted to develop a nanotechnology research program plan focusing on the area of safety.

Problem Statement
Nanoscience has the potential of developing self-healing materials, nanoscale sensors, applications in medicine, and other areas such as optics, electronics, computer science and so on. The promises of nanotechnology are far reaching. At this stage in the technology development, the FHWA needs to develop a plan for including this rapidly growing technology and science into its Advanced Research Program. Establishing a collaborative relationship with organizations leading this effort in government, industry, and academia should be an early step in this process. For example, the National Science Foundation (NSF) is the coordinator of the NNI program.

The FHWA Advanced Research Program is currently engaged in a small number of nanotechnology projects with very modest funding. A program plan for incorporating nanotechnology into the Advanced Research Program in a much larger scale is needed.

Method / Approach
This effort would entail the development of a program plan in the area of nanotechnology. Review of the technology and coordination with lead organizations in this area will need to be established. Areas of safety where this technology can produce countermeasures or treatments over the near- and far-term should be identified.

The results of this effort will be a research program plan with a road map, specific projects, and funding.

Project Duration
This project is projected to last approximately twelve months. Given the rapid growth of the area and significant increase in funding levels by the Federal Government, it behooves the FHWA to rapidly develop a plan and form the necessary relationships in the near term.

6.6 Summary

As mentioned in the introduction to this White Paper, one of the guiding principles was to propose a few Advanced Research projects that were felt to be cross-cutting and with the potential for significant pay-off. The projects can be ranked ordered in terms of potential value and likelihood of success.

(1) Understanding the driver
Development of a driver modeling structure
Development of a Prototype Driver Model
Development of a Driver Model

This set of projects are overall highly rated in terms of potential pay-off. However, as with any modeling effort of this magnitude there are potential risks. The suggestion of breaking the program into the above three projects serves to minimize risk. Also, this type of structure presents the opportunity of learning from research and analysis efforts and modifying subsequent steps in the research program.

(2) Data Collection/Analytical Tools
Evaluation of advanced sensors and data mining techniques
Development of safety decision aids for planners

The decision tools for planners has a very high pay-off potential. Of the above two suggested projects in this area this would be the more highly rated.

(3) Advanced Technology for Countermeasures
Evaluation of nanotechnology for safety countermeasures

The FHWA is already conducting work in this area. There are 8 projects in the area of nanotechnology in the Advanced Research Program. The suggestion here is to more fully evaluate this technology and to develop a more comprehensive research program in this area. The proposed program development task is relatively low risk, however, the potential exists for very high pay-off in the long run. Estimating the impact of nanotechnology on highway safety today would be like trying to predict the impact of modern computers to traffic control and traffic management in the 1950s.