1.0 Executive Summary

This report presents a set of five independent white papers on topics selected by the National Highway Research and Technology (R&T) Partnership, plus an additional chapter that attempts to integrate the set of research recommendations proposed in the white papers. The full statement of work (SOW) for this project is appended to this chapter. It is important to note that this is a small-scale project with limited hours for the white-paper authors. Indeed, the original SOW specified a maximum limit of fifteen pages for each paper; this limit was deleted to allow the authors to respond to useful feedback provided by reviewers from the R&T Partnership Steering Committee. Responses to this feedback are contained in each white paper. In most cases, since the reviewers did not receive a copy of the SOW, their helpful suggestions exceeded the scope of this project. Nevertheless, each author made a serious effort to address most of the issues raised despite an extremely limited number of hours remaining in the project for revision.

1.1 Development of the White Papers

The charge for these papers originated in a Safety Research Agenda Planning Conference held by the R&T Partnership in Irvine, California Sept 17 and 18, 2002. The theme of the conference was Highway Infrastructure and Operations, one of eight safety research themes in the National Highway Safety Research Agenda. The conference brought together stakeholders, from state highway agency researchers and traffic engineers, university researchers and research administrators, private sector researchers and representatives from the Federal Highway Administration, to identify highway safety research needs. This was the initial process to identify and prioritize research needs and knowledge gaps in the following areas:

- Run-off-road accidents
- Intersection safety
- Intelligent infrastructure initiative
- Human factors
- Work zone safety.

Working groups in each of these research areas produced a tentative list of critical research needs. The goal was to produce a set of candidate projects that over the next five years could gain valuable knowledge that would improve highway safety.

Since the focus of the conference was making progress in these key areas, the rationale for the selection of the areas was not debated during the conference. The topics were derived from earlier work of the R&T Partnership which has been articulated in an April 2002 report titled Highway Research and Technology: The need for greater investment. This report identified (Table 2) the following R&T themes and emphasis areas for Highway Infrastructure and Operations:

- Human factor safety guidelines
- Consequences of leaving the road
- Intersection safety
- Intelligent infrastructure initiative
- Work zones
- Inclusion of safety in the highway design process.

Table 1 of the report estimated an annual cost of $30 million over a 5 year time period for the Highway Infrastructure and Operations R&T theme.

The goal of this report is to expand on the projects suggested at the Irvine Planning Conference by giving greater detail and adding any important projects that might have been omitted by the working groups. As discussed in the SOW (Appendix A) the original plan called for a white paper on each of the five topics listed above plus a sixth chapter on Advanced projects that cut across the other areas. However, the paper on intelligent infrastructures, originally planned to be written outside this contract by a Federal Highway Administration staff member, was cancelled due to competing priorities at Turner-Fairbanks Highway Research Center.

In order to minimize contracting delays, this report was assigned as Task 10 of the Federal Highway Administration IDIQ support contract, "Technical Support and Assistance for the Federal Highway Administration's (FHWA's) Human-Centered Systems Team" DTFH61-01-C-00049. The prime contractor is the University of Michigan Transportation Research Institute (UMTRI) supported by an all-star team of public and private sub-contractors including Battelle Human Factors Transportation Center, Bellomo-McGee, Inc., Cambridge Systematics, Center for Applied Research (CAR), Georgia Institute of Technology, University of Iowa, Texas Transportation Institute, TransAnalytics, LLC., Transportation Research Corporation, Virginia Polytechnical Institute & State University Center for Transportation Research, Westat, Inc., and William H. Levison Associates . In order to avoid contractual delays that would be required to add new sub-contractors to the team, white papers were assigned to these sub-contractors contingent upon staff availability. Table 1.1.1 shows the staffing for each white paper.

Table 1.1.1 Assignment of IDIQ team members to white paper topics.

Run-Off-Road	Intersection Safety	Human Factors	Work Zones	Fundamental Advanced Research
Westat	BMI-SG	UMTRI	TTI	Cambridge Systematics

1.2 Results

Each white paper author was instructed to address statistical evidence from national data bases, knowledge strongholds and gaps, critical future highway issues (a new topic added in the revision process), and to generate a list of research topics and projects. Each topic was classified

as Applied or Advanced research. Likelihood of success, defined as completing the project on time and within budget and either generating useful countermeasures (Applied projects) or building a firm foundation for useful countermeasures (Advanced projects), was rated on a five-point scale. Project costs and durations were also estimated. Summary tables for each white paper are presented in the following sections.

Run-off-road

Category	Project Title	Type of Research	Likelihood of success (1-5 scale)	Duration (months)	Cost (in millions)
Run-Off-Road	**ROR 1**: Use of Rumble Strips on Non-Freeways	Applied	5	36	1
Run-Off-Road	**ROR 2**: Development of a System of TCDs to Reduce ROR Crashes at Curves	Applied	4	18	1
Run-Off-Road	**ROR 3**: Optimizing the Net Benefits of Delineation	Applied	4	36	1
Run-Off-Road	**ROR 4**: Development and Application of a Roadside Inventory Database	Advanced	3	24+	1.5

Table 1.2.1

Intersection Safety

Category	Project Title	Type of Research	Likelihood of success (1-5 scale)	Duration (months)	Cost (millions)
Accident Causation	**IS 1a:** Magnitude, Characteristic, & Causation of Intersection Accidents	Advanced	Moderate to High, 4	36	$1.5 - 2M
	IS 1b: Establish Root Causes of Driver Error	Advanced	Moderate 3	24	$0.5 – 0.75 M
Relationship of Safety to:					
a. Traffic & Operational Features	**IS 2a-1:** Safety Impacts of Alternative Intersection Controls	Advanced	Moderate 3	36 – 60	$1.0 – 1.5 M
	IS 2a-2: Safety Effects of Alternative Left Turn Phasing	Applied	Moderate 3	24	$0.3 M
b. Traffic Control Devices	**IS 2b:** Safety effects of alternative signal layouts	Applied	Moderate to High, 3	36	$0.3 M
c. Design Features	**IS 2c:** Intersection Sight Distance	Advanced	Low to Moderate, 2	24 – 36	$0.5 M
Effectiveness of Counter-measures	**IS 3:** Effectiveness of various countermeasures for reducing accidents	Applied	Moderate to High, 4	84 for all phases	$2.0 M
Advanced Technology	**IS 4:** Effectiveness of & Driver Response to Automatic All-red Signal Extension System	Applied	High, 5	6	$0.05 - $0.1 M

Table 1.2.2

Human Factors

Category	Project Title	Type of Research	Likelihood of success	Duration (Months)	Cost ($1,000,000)
Human Factors Cognitive Models	**HF 1a:** Computational Driver Model: WE (Whole Enchilada)	Advanced	3.5	144	12
	HF 1b: Computational Driver Model: Light	Advanced	4.0	60	5
Human Factors Information Overload	**HF 2:** Processing Multiple Sources Of Information	Advanced	4.0	60	10
Human Factors Speed Control	**HF 3:** Understanding Speed Selection	Applied	3.0	48	8
Human Factors Perception/Attention	**HF 4:** Look but not see	Applied	2.5	36	4
Human Factors Basis for Design Standards	**HF 5:** Design Driver	Applied	4.5	18	0.3
Human Factors Decision Rationality	**HF 6:** Risk Homeostasis	Applied	2.5	28	1
Human Factors Simulator Generalization	**HF 7:** Driving Simulator Validity	Applied Methodology	4.5	42	4.5

Table 1.2.3 Prioritized list of research projects. Likelihood of success ranges from Very Low (1) to Very High (5).

Work Zones

Category	Project Title	Type of Research	Likelihood of success (1-5 scale)	Duration (months)	Cost (Millions)
Research Methodology – WZ Exposure Data	**WZ 1a:** Estimate WZ Exposure Characteristics from FMIS	Applied	High 4	30	$1M
	WZ 1b: Develop VMT Temporal Distributions to Estimate WZ Exposure	Applied	Very High 5	18	$0.5M
Research Methodology – WZ Crash Data	**WZ 2a:** Incorporate New WZ Data Elements into CDS Crash Investigations	Advanced	Moderately Low 2	60	$2M
	WZ 2b: Investigate Likelihood of Work Zone Crash Reporting	Applied	Very High 5	18	$0.5M
Determine WZ Crash Causation	**WZ 3a:** Feasibility and Validity of Region-wide WZ Crash Risk Estimation Techniques	Advanced	Moderate 3	30	$1M
	WZ 3b: Project-Level Crash Consequences of Work Zone Design Features	Applied	Moderate 3	60	$2.5M
Identify/Evaluate Countermeasures to Mitigate WZ Crash Risk	**WZ 4a:** Improving the Understanding and Measurement of Driver Behavior in High Driver Workload Environments	Advanced	Moderate 3	36	$1.5M
	WZ 4b: Evaluate Dynamic Queue End Warning Systems for WZ	Applied	Moderately 3	60	$1.5M
Develop/Apply/ Evaluate WZ Management Procedures	**WZ 5a:** Analyze State WZ Monitoring and Management Programs and Procedures	Applied	High 4	48	$1M

WZ = Work Zone
FMIS = Financial Management Information System
CDS = Crashworthiness Data System
GES = General Estimates System
VMT = Vehicle-Miles-Traveled

Table 1.2.4

Fundamental Research

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[1]

Table 1.2.5

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

1.3 Appendix A: Statement of Work

Task Order Statement of Work for IDIQ (DTFH61-01-R-00049):
Submitted by The University of Michigan
Development of Critical Knowledge Gaps and Research Efforts in Support of the Safety R&T Partnership Agenda

Background: In April 2002, the National Highway Research &Technology Partnership published its report, ***Highway Research and Technology: The Need for Greater Investment***, with the purpose of establishing a document of priority research, development, and technology program areas for enhancing the opportunity for all parties involved in highways to coordinate and collaborate on conducting these priority areas. The report indicated that the working group to the highway safety portion of the Partnership proposed to refine and conduct a pilot implementation of coordination and collaboration in the Highway Infrastructure & Operations safety theme. This theme was one of eight major safety theme areas in the Agenda. [The other themes are Safety Management and Data Systems, Driver Competency, High Risk Driving, Light Duty Vehicle Safety, Vulnerable Road Users, Truck/Bus Safety, and Post-Crash Management.]

A Safety Research Agenda Planning Conference was help on September 17 & 18, 2002, in Irvine CA, to address how to proceed with the objective for coordination and collaboration in the Highway Infrastructure & Operations safety theme. The two fundamental goals of the Conference were to:

- Generate a high-level agenda process for the systematic identification of highway safety research based on stakeholder needs, the development/conduct of high-quality coordinated research, and implementation of results.

- Initiate the process of identifying and prioritizing critical highway safety research needs and information gaps in the following areas: (1) Run-Off-Road, (2) Intersection Safety, (3) Human Factors, (4) Work Zones, and (5) Fundamental Advanced Research.

The safety conference attendees were comprised of state highway agency researchers and traffic engineers, university researchers and research administrators, private sector researchers, and representatives from the Federal Highway Administration. The three products emerging from the conference were: (1) a preliminary safety research agenda process, (2) recommendations pertaining to the quality of research, and (3) the identification of critical infrastructure safety research needs. It is this last product that additional assistance and input is sought via this Task Order.

Objectives:

The objectives of this effort are:

- Develop writing guidelines for white paper authors,

- Produce five preliminary white papers identifying critical research needs in the areas of Run-Off-Road, Intersection Safety, Human Factors, Work Zones, and Fundamental Advanced Research, (A sixth white paper on Intelligent Infrastructure Initiatives will be written outside this task order).
- Produce an Integration Paper which identifies the cross-cutting aspects of the six white papers, and
- Develop a quantitative approach to evaluating the ultimate list of safety research topics which will be generated using the seven papers mentioned above as a starting point.

Tasking:

Task 1 – Guidelines for White Paper Authors

In order to maximize the uniformity in approach which will allow comparison between the white papers and lead to optimizing the integration of potential research topics from the six white papers, UMTRI shall develop guidelines for the white paper authors. The guidelines shall suggest a common structure for the white papers.

Suggested guidelines might be:

- Length of paper – no longer than 12 to 15 pages
- Breakout of applied or advanced research
- Section suggestions
    - magnitude of the highway safety problem (number of fatalities and injuries)
    - estimate of the application of knowledge
    - likelihood that the research area project would produce successful or intended results

All white papers will include a final list of specific research topics to be rated in Task 4.

Suggested guidelines shall be submitted to the government within 4 weeks of the initiation of the contract. The government shall provide comments on the guidelines to UMTRI in 2 weeks. Within 6 weeks of the initiation of the contract, the guidelines will be finalized and sent to the white paper authors. Task 1 will be performed by UMTRI.

Task 2 - White Papers

The six topic areas are a mix of highway safety problem areas (run off road, intersection, and work zones), as well as a solution-based type area (intelligent infrastructure initiatives) and of a cross cutting nature (human factors and advanced technology). Accordingly, there will be a level of overlap in the white papers. The authors should address the topics individually, as well as to incorporate appropriate considerations of the intelligent infrastructure initiatives and human factor research projects into the other four problem areas.

Task 2A – Run-Off-Road

Run-off-road (ROR) research needs to address two major questions: why drivers run off the road and what happens when they leave the road. Specific knowledge is needed in two areas: (1) causes of roadway departures (i.e., what happens before the vehicle crosses the edge line); and

(2) roadside countermeasure effectiveness (i.e., what can be done to reduce crash consequences after the vehicle crosses the edge line). Of particular interest is how highway infrastructure technology can mitigate R-O-R crashes.

The highest-ranked research topics rated by the ROR breakout group were:

- Use of one-pass van to inventory the roadside features –digitize roads for vehicle /roadway interactions
- Methods for choosing ROR sites, corridors, treatment programs
- Rumble strips on narrow paved shoulders
- Intelligent Infrastructure warning systems – field test of driver response
- Relationship of simulation and crash test results to real-world crash injuries
- Safer ditch design for rural two-lane roads
- Tree removal tradeoff research
- Vehicle/roadside interaction (Roll over, tripping effects, etc. by vehicle type)

Task 2A will be performed by Westat.

Task 2B – Intersection Safety

Intersection safety research was viewed as a high-priority/high-payoff area by the R&T Partnership members due to the fact that crashes are highly concentrated at intersections. The breakout groups considered a systematic review of crash data to decide what research topics deserve priority. Fundamental intersection safety issues were identified as: (1) effectiveness of stop-sign vs. signalized traffic control, (2) effectiveness of actuated vs. semi-actuated vs. fixed time signalization, (3) relationship between signal-timing decisions and safety, and (4) safety effects associated with traffic flow characteristics

Specifically identified research topics are as follows:

- Safety effects of cross-sectional elements at intersections
- Safety performance of roundabouts
- Analytical tools/models for traffic engineers & planners to consider the safety consequences of intersection safety and design
- Safety effects of transitional elements moving from corridors to intersection approaches
- How to accommodate various users (pedestrians, bicycles, trucks, etc.) for different scenarios
- Safety effects of traffic-calming devices/perceptual measures
- How does the culture of road user behavior evolve and how can it be influenced
- Relationship of ISD safety
- Analytical tools to identify which intersections to provide selective enforcement

Task 2B will be performed by BMI.

Task 2C – Human Factors

Identified research gaps were guided by the need to determine what is in the driver's head, emphasizing driver observational and cognitive processes that affect safety-related actions. Certain modeling applications, i.e., development of a Computational Cognitive Driver Model

and extended work on the IHSDM, received the highest ratings for their potential to produce important results; however, the estimated costs for these applications were high. Continued research on the Design Driver emerged as the most promising study area, i.e., likely to produce important and timely results with a high probability of success while requiring minimal resources of time and funding.

Specifically identified research topics are as follows.

- Understanding the driver via application of a computational cognitive model
- Determining sources of driver overload from multiple sources of information
- Understanding speed selection, i.e., contributing factors to driver loss of control
- Causes of look-but-did-not-see crashes, i.e., why some drivers fail to notice critical elements in the visual field
- Development of a design driver as a basis for human factors standards, to assist in understanding the effects changing demographics and related factors
- Assessing the validity of homeostasis theory, an approach to risk acceptance and compensatory behavior
- Continue MDAI data collection, via updating the Indiana Tri-level study

Task 2C will be performed by UMTRI.

Task 2D – Work Zones

Existing work zone crash data, describing a wide variety of crash types, is highly diverse and lacks consistency. While fragmented studies have been undertaken in many states, there is no uniform database that is suitable to adequately establish causation. Additional data elements e.g., (exposure measures) are required for statistically valid cause and effect studies. Critically lacking is a consistent research methodology supporting a synthesis of the varied databases. Once such a methodology is developed, it will then be necessary to conduct controlled studies in order to develop a conclusion regarding causation. Such an effort would entail considerable time and funding. In the interim, improved work zone management procedures are necessary to maximize the safety benefit of existing traffic control techniques.

Specifically identified research topics are as follows:

- Develop a research methodology to compile detailed work zone crash and exposure information
- Apply the methodology to determine crash causation
- Identify and prioritize crash types and causal factors to reduce work zone injuries and fatalities
- Identify countermeasures to mitigate risk based on crash exposure information
- Conduct controlled experiments to evaluate promising countermeasures
- Develop and apply management procedures to control consistency and quality

Task 2D will be performed by TTI.

Task 2E – Fundamental Advanced Research

The fundamental/advanced research paper could include, but not be limited to, research of new information, computational analysis, methods, and modeling, materials, and technologies that

could be used to improve highway safety or to better understand highway safety issues or the research of those issues. While fundamental/advanced research will be a separate white paper, if there are priority research projects associated with the five topic areas from the Irvine Conference, those fundamental/advanced research projects should also be included and ranked in those topic areas.

The draft of the white papers shall be due 17 weeks after initiation of contract. The government will have 4 weeks to review the white papers and make comments. Telephonic communications between government personnel and the white paper authors may be necessary to resolve certain issues. The final white papers shall be due 23 weeks after the initiation of the contract.

Task 2E will be performed by Cambridge Systematics.

Task 3 – Integration White Paper

As mentioned in the introduction to the white papers in Task 2, there will be overlap in the white papers. For instance, it is easy to understand that research can, and perhaps should, be conducted which covers intersections, speed management, and intelligent infrastructure. This white paper needs to address how the individual white papers fit together. This white paper should be a synthesis of the ideas and research topics contained in the other white papers. It should make recommendations which will aid those who will decide on the list of research topics to be evaluated.

This attempt at synthesis will be a difficult one so this integration white paper should be considered a first approximation at integration of safety research topics.

The draft of the Integration white paper shall be due 25 weeks after initiation of contract. The government will have 2 weeks to review the Integration white paper and make comments. Telephonic communications between government personnel and the white paper author may be necessary to resolve certain issues. The final Integration white paper shall be due 29 weeks after the initiation of the contract.

Task 3 will be performed by UMTRI.

Task 4 – Quantitative Approach to Evaluating Safety Research Topics

Based on the white papers (and perhaps other input), a list of safety research topics for each of the six research areas will be developed. These topics will then be evaluated by subject matter experts. Decisions on which safety research topics to pursue will be based to a large degree on the ratings of the expert evaluators. In order for the expert ratings to be interpreted in a uniform and consistent manner, a quantifiable approach must be developed. The approach must allow for the comparison between the ratings within the topic area and across topic areas.

Fortunately, a methodology for rating and comparing research topics has already been developed and validated under the FHWA ATIS/CVO project (Kantowitz, Lee & Kantowitz, 1997). It is based on the general linear model. The study showed that this psychometric model is fairly

insensitive to criteria weightings: as long as the ranks of the weightings are unchanged the precise values are not that important. In order to apply this method we need (a) a list of research topics and (b) a set of criteria. The topics will be generated in Task 2. Criteria used in the earlier study included Congestion, Safety, Mobility, Environment, Economic, Existing Data, Suitability for Guidelines, Older Drivers, Younger Drivers, Cost and Time to Complete. This set will be modified to suit the goals of the present project. Experts will rate the topics for all criteria on a five-point scale. A spreadsheet model will calculate the most important topics within a category and, more importantly, the most important topics across categories.

Among the items that UMTRI will consider are:

a. Criteria definition – for example:
    - size of the crash problem which will be impacted by the research
    - anticipated portion of the problem that countermeasures from the research would impact
    - degree and length of time that the countermeasures are estimated to be deployed,
    - probability of successful research,
    - research costs, and
    - length of time to perform the research.
b. Scale for each criteria,
c. A weighting system across criteria,
d. Categorization of efforts into those that will result in:
    - ready solutions or strategies/countermeasures that will potentially improve safety (applied),
    - knowledge breakthroughs that can impact safety in a number of indefinable ways (fundamental), and
    - new strategies/countermeasures based upon the fundamental research findings.
e. List of potential project evaluators.

The draft of the "Quantitative Approach to Evaluating Safety Research Topics" paper shall be due 32 weeks after initiation of contract. The government will have 3 weeks to review the Integration white paper and make comments. Telephonic communications between government personnel and the white paper author may be necessary to resolve certain issues. The final "Quantitative Approach to Evaluating Safety Research Topics" paper shall be due 36 weeks after the initiation of the contract.

Task 4 will be performed by UMTRI with expert ratings completed from all team members.